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Japanese Technological Innovation - Implications for Large Commercial Aircraft and Knowledge Diffusion

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ABSTRACT

This paper explores three factors—public policy, the Japanese (national) innovation system, and knowledge—that influence technological innovation in Japan. To establish a context for the paper, we examine Japanese culture and the U.S. and Japanese patent systems in the background section. A brief history of the Japanese aircraft industry as a source of knowledge and technology for other industries is presented. Japanese and U.S. alliances and linkages in three sectors—biotechnology, semiconductors, and large commercial aircraft (LCA)—and the importation, absorption, and diffusion of knowledge and technology are examined next. The paper closes with implications for diffusing knowledge and technology, U.S. public policy, and LCA.

INTRODUCTION

The technological advancements and achievements made by post-World War II Japan are nothing short of extraordinary. The Japanese "economic miracle," as it is often called, remains the focus of scholars and policymakers. Indeed, the number of essays, articles, studies, dissertations, and books dealing with Japan is voluminous and shows no signs of abatement. At the heart of these inquiries is the search for the answer to the two-part question, "What is the secret of Japan's economic success? and once known, "can the secret be applied successfully to the United States' economy?"

Currently, the United States has a bilateral trade deficit with Japan that accounts for about 40% of the overall U.S. trade deficit. Knowing the factors that contribute to Japan's economic achievements and that nation's ability to develop and commercialize technology becomes essential if the United States is to strengthen its ability to compete and partner with Japan in the global economy. The secret of Japan's success is actually a combination of several factors. In this chapter, we have assembled these factors into three groups—public policy, the Japanese (national) innovation system, and knowledge. Japanese public policy (e.g., economic, industrial, and technology) is focused, consistent, pragmatic, and adaptive, and it recognizes that knowledge and technological leadership are critical to national economic performance (He, 1993; Imai, 1991; Komiya, Okuno, and Suzumura, 1988). Although Ergas (1987) considers Japanese technology policies to be unique and, thus, neither "mission– nor diffusion–oriented," these policies do incorporate many "diffusion-like" features identified by Branscomb (1993) and previously in Chapters 3, 4, and 17. Chief among these are the capacity to adjust to technological change across the entire industry structure and the effective diffusion of imported and domestically produced knowledge and technology (Frankel and Kahler, 1993).

Of particular importance is the role played by the Ministry of International Trade and Industry (MITI), the leading state actor in the Japanese economy (Johnson, 1982; Samuels, 1994). MITI maintains close and continual contact with industry, fosters industrial collaboration and the diffusion of knowledge among firms, and uses industry associations and advisory committees to review and endorse technology projects and policies (Cheney and Grimes, 1991). As a matter of

national policy, MITI nurtures the development of such knowledge-intensive industries as aircraft manufacturing as sources of knowledge that can be "spun on" to other industries. It fosters research collaborations, alliances, and linkages as a means of accessing and importing (external) knowledge and technology. MITI also provides low-cost loans and facilitates the creation of such "program partnerships" as the Japanese Aircraft Development Corporation (JADC) in order to promote Japanese industry involvement in a variety of projects, including JADC's participation as a risk-sharing subcontractor in the Boeing 777 project.

Innovation, a catalyst for growth, can be divided into three types—organizational, product, and technological (Makino, 1987). Organizational innovation in Japan has been achieved by streamlining the structure of the company, wisely managing the enterprise (Basadur, 1992; Sakakibara and Westney, 1992), and organizing the production and distribution systems to optimize marketing and export goals. Product innovation in Japan involves the manufacture of goods that reflect customer requirements and are readily adaptable to changes in consumer behavior and spending. Technological innovation in Japan involves the importation, absorption and adaptation of, and the development of new knowledge and technology to produce new products, processes, or services and to improve existing ones (Herbig, 1995). Technological innovation in Japan, as distinguished from that in the United States, is characterized by, among other things, globalization and international networks and international collaboration (Fransman, 1991). It is also distinguished from that in the United States by its culture and patent system (Kotler and Hamilton, 1995) and the use and management of knowledge (Hedlund and Nonaka, 1993).

Japanese companies are exceptional innovators. Japanese firms, as described by Nonaka and Takeuchi (1995), are *knowledge companies* that are constantly importing and creating knowledge, diffusing it throughout the organization, and quickly embodying it in new and existing products, processes, or services. The firms' efforts are assisted by a (national) system of innovation that stimulates research and development (R&D), promotes technological innovation (Odagiri and Goto, 1993), and excels at taking knowledge and technology from around the world and using them to develop and improve products, processes, or services (Cheney and Grimes, 1991). Westney (1993) states that a widespread consensus has emerged on some key characteristics of the technological behavior of Japanese firms, when compared to those in the United States: (a) shorter (product) development time cycles; (b) more effective design for manufacturability; (c) more incremental product, process, and service improvement; (d) innovation dominated by large, rather than small firms; (e) a stronger propensity to competitive matching of products and processes; (f) a greater propensity for interfirm collaboration in developing and diffusing technology; (g) a higher propensity to patent; (h) weakness in science-based industries, and (i) more effective identification and acquisition of external knowledge and technology on a global scale. Japan has created numerous alliances and linkages to compensate for weakness in science-based industries and to acquire external knowledge and technology, a point repeated throughout the paper.

For the past 40 years, Japan has benefitted significantly from the knowledge (explicit and tacit) and technology that have flowed to it from the United States. This largely one-way diffusion of knowledge and technology is the result of proactive participation by both the Japanese government and private sector firms in the importation and diffusion of knowledge (Arrison, Bergsten, Graham, and Harris, 1992). The strategies employed include: (a) explicit or codified knowledge, such as that contained in books, journals, and drawings; (b) tacit knowledge by hiring engineers, scientists, and technicians trained in the U.S. and by sending Japanese to study abroad; and (c) entire product and process technologies through foreign and direct investment (Imai, 1991; Odagiri and Goto, 1993; Okimoto, 1986). (See Peck and Goto, 1981, for the importation of [external] knowledge and technology and their use by Japan to promote economic growth.) In addition, the Japanese have benefitted from the learning-by-doing and learning-by-

using acquired through the licensed manufacture and production and co-production of U.S.-made products and the maintenance and repair of U.S. aircraft. Japan has a number of governmental and quasi-governmental organizations such as the Japanese Information Center for Science and Technology (JICST) that collect information worldwide in virtually all fields of pure and applied science and technology. (See Morita, 1991, for insight into the infrastructure of Japanese information.) Further, the Japanese have mastered what has become known as "competitive intelligence," the collecting, analyzing, delivering, and using of publicly available information for competitive advantage (Hansen, 1996; Kokubo, 1993). Various government policies, such as the mandatory six years of pre-college English training required of Japanese students, increase the usability and value of foreign language information.

The diffusion of knowledge is encouraged by the fact that Japanese industries and firms have developed cooperative vertical, and sometimes horizontal, relationships. The *keiretsu*, a group of cooperative, and often subcontracting, firms is an example (Johnson, 1982; Samuels, 1994). A long-term, semi-fixed relationship between users and suppliers and among affiliated firms, subcontractors, vendors, and others enables the participants to share information about the nature of technology and the products involved. The long-term transaction involved in such relationships includes not only an economic component, but also a social one comprised of trust, loyalty, and power (Imai, 1991). Finally, the importation, absorption, diffusion, and application of knowledge and technology are facilitated by a number of factors in the Japanese culture (Stewart, 1987; Tudjman, 1991; Phillips, 1993), a point on which we expand in the background section of the paper.

Three factors—public policy, the Japanese (national) innovation system, and knowledge—that influence technological innovation in Japan are presented in this paper. To establish a context for the chapter, we examine Japanese culture and the Japanese patent system in the background section. A brief history of the Japanese aircraft industry as a example of the importation, absorption, and diffusion of knowledge and technology to other industries is presented. Japanese and U.S. alliances and linkages in three sectors—biotechnology, semiconductors, and large commercial aircraft (LCA)—and the importation, absorption, and diffusion of knowledge and technology are examined next. The paper closes with implications for diffusing knowledge and technology, U.S. public policy, and LCA.

BACKGROUND

A number of factors, individually and collectively, affect the diffusion of knowledge at the individual, organizational, national, and international levels and the process of technological innovation. To establish the chapter's context, two factors—Japanese culture and the Japanese patent system—are presented that influence the organization and diffusion of knowledge in Japan serve to distinguish innovation in Japan from that in the United States.

Japanese Culture

Cultural, ontological, and epistemological principles influence the organization and diffusion of knowledge in a society (Crane, 1995). A variety of cultural determinants is responsible for the unique position that knowledge holds in Japanese society. Although the Japanese attitude towards science and the organization of knowledge assumes similar organizational and phenomenal forms as in Western countries, the attitude is based on different cultural principles. For example, in Chapter 3, we explained that in the U.S., the results of science that are paid for with public (i.e., taxpayer) money are considered to be public knowledge. Hence, scientific

knowledge is published and made accessible to any and all for critical assessment. Science in Japan is formed *not* as *public knowledge* but as *corporate knowledge*; knowledge belongs first to the corporation; it is acquired and developed, organized, and used chiefly within the corporation as *insider knowledge*. Thus, knowledge is neither individual nor public property (Tudjman, 1991). Furthermore, in Japan, knowledge is a commodity and possessing knowledge is a privilege.

Certain of these determinants—the propensity to work together in groups, a willingness to subsume individual interests to the greater good, and an emphasis on consensual decisionmaking— have a direct bearing on the ability of Japanese firms to form alliances and to compete in international markets. Certain determinants or attributes in Japanese culture—collectivism, *Wa* (harmony), *Giri* (obligations and expectations), and acceptance of authority—influence the organization and diffusion of knowledge in Japan. (See Herbig, 1995, Chapter 6.) Researchers have investigated how these attributes affect the communication of knowledge between Japan and Western cultures, principally the United States (Ford and Honeycutt, 1992; Goldman, 1994; Kato and Kato, 1992; Maher and Wong, 1994; McNamara and Hayashi, 1994; Ohsumi, 1995).

In following section, we review six cultural determinants—(a) group think vs. individual expression, (b) differences in high-context and low-context communications, (c) attitudes about contractual agreements, (d) the influence of religion on Japanese culture, (e) "mental telepathy" and "apparent" vs. "real" messages as communications norms, (f) surface/bottomline messages, and (g) the Japanese preference for informal (oral) communications over formal (written) communications—to assess how these determinants influence the organization and diffusion of knowledge in Japan. Although our review provides useful insights into understanding how culture affects the organization and diffusion of knowledge in Japan, our review is not exhaustive. Missing from this discussion, for example, is the influence of linguistics and non-verbal communication.

Group think vs. individual expression. Perhaps the most striking feature that distinguishes the organization and diffusion of knowledge in Japan from that of Westerners is the concept of group think based on hierarchy. Ford and Honeycutt (1992) trace the existence of a hierarchical structure to Confucianism that was brought from China to Japan during the fifth century. Confucianism teaches that "the need for submission to elders and those of superior position in the group" is a prerequisite of a society (Ford and Honeycutt, 1992, p. 31). Group think is an extension of the holism in society that provides a basis for corporate decision making (McNamara and Hayashi, 1994, p. 7). Individualism, which is cherished in the West, is not considered a virtue in Japanese society. The Japanese expression, "the nail that stands up will be pounded down," exemplifies the clear distaste for individualism that most Westerners note as one of the distinct features of Japanese unwritten codes (Maher and Wong, 1994, p. 43; Buckett, 1991, p. 88). In considering the role of the individual in society, Nakane (1972) asserts that an individual is defined by an attribute that makes up a frame. A group or a frame is formed when individuals share common attributes (Nakane, 1972, p. 7). Thus, the individual has meaning only within the context of a group. The notion of collectivism is ubiquitous from private to public, from family to corporate organizations, and from local to national levels. The emphasis on harmony among individuals in groups mirrors "the communal ethic of Shinto" (Maher and Wong, 1994, p. 43); it is assumed that the homogeneous nature of Japanese society makes it possible to carry out group think.

High context/low context communication. Hall and Hall (1987) define a high context (HC) communication as one in which most of the information is already in the person, while very little is in the coded, explicit, transmitted part of the message. A low context (LC) communication is

just the opposite; that is, the mass of the information is vested in the explicit code (p. 8). Japan has never been invaded by another nation. Thus, a homogeneous and isolated Japanese society could afford to foster HC communication in which almost everyone understands the beliefs, principles, and assumptions about how to go about interacting with people (McNamara and Hayashi, 1994, p. 10). Conversely, the United States is a heterogeneous, LC society in which a melting pot approach to communication is the norm. In a society whose citizens have diverse national and ethnic backgrounds, it is inevitable that everything to be communicated to others has to be described explicitly. Assumptions also have to be explained because there is no single set of beliefs or rules of conduct governing society. Therefore, "explicit digital and verbal communication is an essential element in Western, and especially American, culture" (McNamara and Hayashi, 1994, p. 10). It is worth mentioning that there is always a danger in classifying everything in dichotomous fashion. For example, Inaba (1988) argues that Hall and Hall's (1987) classification of Japanese and U.S. citizens as HC and LC respectively may be shortsighted, for it excludes nonverbal behavior. However, the literature supports Hall and Hall's (1987) assertions about Japanese and U.S. communications norms.

Contractual agreements. The concept of a contractual agreement is foreign to the Japanese. Nakane (1972) states that "any sense of contract is completely lacking in the Japanese, and to hope for any change along the lines of a contractual relationship is almost useless" (p. 80). The influence of common law may provide the foundation of contractual agreements that are so important in the United States. Goldman (1994) suggests that it is so important for Japanese to acknowledge other people based on *ningensei* or "human beingness" that there is no room for logic or rules to be laid out (p. 235). Ohsumi (1995) also stresses the fact that U.S. society is based on rules, but Japanese society has low regard for rules. The Japanese preference to do without contracts and rules may be related to such cultural attributes as group think and HC. In Japanese society, it is assumed that everyone communicates under the same preexisting set of beliefs; therefore, there is no need to spell out explicitly what is expected or to establish written rules.

The influence of religion. In Japan, religious beliefs are assumed to be an integral part of an individual's history. Although Japanese society is experiencing a noticeable decline in religious affiliation, religious ritual, symbolism, and attitude continue to play an important role among the Japanese people (Maher and Wong, 1994). The Japanese are deeply influenced by ideas and concepts coming from animism, Buddhism, Confucianism, Shinto, Taoism, and Zen. Elements of Confucianism, Buddhism, and Shinto continue to affect the daily lives of the Japanese although the trend toward secularism noted recently in the West actually began almost three centuries ago in Japan (Reichauer and Jansen, 1995, p. 203). The strong work ethic and an emphasis on harmony come from Confucianism. Matsuda (1991) correlates the ideas of group actions, shared responsibility, harmony, and a strong loyalty to the group with Buddhism, which teaches that everything in nature has life, and therefore one's life is a part of nature (p. 106). Shinto has been the official national religion since the Meiji Restoration of 1868. Originating from Buddhism, Shinto evolved as a set of beliefs associated with the foundation myths of Japan and with the cult of imperial ancestors. Shinto focused attention within a Japan that was becoming more nationalistic and "eventually came to seek a new unity under symbolic imperial rule" (Reichauer and Jansen, 1995, p. 209).

Traditional mental telepathy: *Ishin-denshin* and *Haragei* . As a homogeneous society, Japan has nurtured its people to communicate according to the principle of *Ishin-denshin* or "if it is in one heart, it will be transmitted to another heart" (Kato and Kato, 1992, p. x). In essence, a message should be conveyed to a receiver without using many words because both parties are capable of understanding each other wordlessly. Gudykunst and Nishida (1993) describe

Inshin-denshin as "traditional mental telepathy" (p. 150), for it assumes that a transmitted message will be understood by a receiver. *Inshin-denshin* is closely related to another Japanese concept *haragei*, literally meaning "belly language." *Haragei* can be understood as "the center of abdominal respiration that is in charge of *ki*, which is the mind and the body that acts almost like air that is inhaled and exhaled by a person" (Lebra, 1993, p. 65).

Surface/bottomline messages (*Tatemae/Honne*). Human relationships in Japan have two sides, *tatemae* and *honne*. "*Tatemae* is front face or what is presented and *honne* is true feelings privately held" (Hall and Hall, 1985, p. 61). "*Honne* is what a person really wants to do, and *tatemae* is his submission to moral obligation" (Gudykunst and Nishida, 1993, p. 152). The Japanese have two modes of communication; *tatemae* is a formal communication and *honne* is the language of the heart (Kato and Kato, 1992, p. 22). *Tatemae* usually is exchanged during business hours and *honne* surfaces outside office hours. The meanings of *tatemae* and *honne* are closely associated with what Ford and Honeycutt (1992) call "surface or appearance vs. result or bottomline" (p. 29). The same concepts can be thought of as "the apparent versus real" (Maher and Wong, 1994, p. 44). The Japanese tend to place greater importance on process than the results (Ford and Honeycutt, p. 29). Thus, such seemingly meaningless rituals as an exchange of business cards and conversations without much essence in *tatemae* mode can be viewed as a way of showing respect for each other.

Emphasis on informal communication. The literature establishes that the Japanese rely heavily on informal communication (Kato and Kato, 1992). Personal contact or "knowing who" is extremely important. Of course, informal communication is very important in the U.S., but for the Japanese, informal communication has some peculiar features. For example, "the old boys' network provides links to practically every board room, laboratory, and factory in Japan" (Cutler, 1989, p. 22). This network is based on alumni networks of major colleges and universities that actually connect academia, government, and industry. Kokubo (1992) notes that "researchers make courtesy calls on university professors, who serve as middlemen to relay information to their networks of alumni" (p. 34). In addition to relying on colleges and universities, the Japanese extend their networking capability through such various "people links" as professional societies, consulting groups, collaborative work groups, and professional and technical conferences and meetings (Cutler, 1989, p. 20).

Information gathering through informal contacts is central to the idea of Japanese competitive intelligence. Kokubo (1992) states that "competitive intelligence consists of: (a) gathering technical information, (b) distributing the acquired information to "linking agents," and (c) analyzing and arranging information for decision-making" (p. 35). In Japanese business and industry, each project has a "champion" who works with staff members in the technology information office and patent department, senior researchers, and information professionals (e.g., librarians). Japanese managers at all levels are expected to gather, disseminate, and utilize the latest information available through the company grapevine and from industry-wide conferences and trade shows, *zaibatsu* groups or clubs, and business, professional, and technical societies (Kokubo, 1992).

Japanese Patent System

Intellectual property is the broad definition for intangible assets owned or claimed by individuals, corporations, or other entities that are the product of creativity, knowledge, and innovation. Intellectual property rights are the legal rights that are provided for the various forms of intellectual property—patents, copyrights, service marks, trademarks, mask works, industrial designs, and trade secrets. As noted by Kotler and Hamilton (1995), the World Intellectual Property Organization (WIPO) defines intellectual property as:

> the rights relating to literary, artistic, and scientific works; performances of performing artists, phonograms, and broadcasts; inventions in all fields of human endeavor, scientific discoveries; industrial designs; trademarks, service marks and commercial names and designations; protection against unfair competition; and all other rights resulting from intellectual activity in the industrial, scientific, literary, or artistic fields. (p. 11)

A patent is a legal right granted for a limited period of time by a national government or an international intergovernmental authority to individuals so that they may profit from their inventive labor. Patents are generally granted for new or improvements to existing products, processes, or designs. (A patent awarded by the United States government grants its owner, or holder, the right to exclude others from making, using, or selling the product, process, or design in the U.S.) A patent system fulfills two roles—it provides legal protection for inventions and it ensures that knowledge concerning the invention is made known to the public.

Prologue. A patent provides an inventor the legal means of preventing others from imitating (i.e., producing and selling) the product, process, or design covered by the patent. This protection also places the patent holder in a position to license the product, process, or design to others in exchange for compensation. As noted in Chapter 3, it is the expectation of monetary reward that theoretically provides the incentive to invent. Without protection, inventors could not receive a return on their investment. Absent the expectation of a return on investment, the incentive to invent is all but curtailed. Patents have been praised by some as providing the economic incentives to innovate and condemned by others for creating monopolies that stifle competition and create artificially high prices for consumers. As a means of appropriating economic return on investment, patent protection is rarely so strong as to prevent an imitator from circumventing it. Mansfield (1989) determined that inventing around a patent required substantially less cost and takes less time than the original invention. Despite its imperfections, the patent system appears to provide more protection and incentive to invent than those (systems) designed to replace it. Economists have determined that "inventive activity responds elastically to the demand price of an invention, implying that it is influenced by the correct incentive policy" (Herbig, 1995, p. 56). This, states Wyatt (1986), makes the private rewards proportional to the potential social value of inventive output, which is precisely what the patent system is designed to achieve. A patent system encourages the creation of ideas that represent departures from accepted practice, particularly radical innovations (Herbig, 1995); inspires inventors to pursue different or seemingly foolish ideas; spurs innovation; is important to a firm's corporate strategy; and is a critical component of technology policy. The importance given patents is reflected in the Uruguay Round of GATT (General Agreement on Tariffs and Trade) in which intellectual property rights, of which patents are a part, were a key part of GATT discussions.

A U.S. perspective. In the United States, patent rights are protected by statutes authorized by the Constitution, Article 8, that states

> The Congress shall have the Power...To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries.

The legal framework established by the above quoted section of the Constitution emphasizes the rights of the individual inventor. The U.S. statute is contained in Title 35 of the United States Code and is interpreted and applied by the federal courts. The U.S. Patent Act of 1952 is a codification of common law, judicial precedent, and statute dating back to 1790. The patent statute has been revised substantially on several occasions since it was created in 1790, the most recent occurred in 1952. In the United States, patents are issued for significantly differentiated items, are secret until issued, and the examination and granting of patents rights is the purview

of the U.S. Patent and Trademark Office, an agency of the U.S. Department of Commerce. In 1993, the United States earned over $20 billion from international technology licensing. Correspondingly, the international theft of intellectual property reportedly cost American companies nearly $24 billion annually (Kotler and Hamilton, 1995).

As part of a decade of new technology policy initiatives undertaken during the 1980s and early 1990s, the U.S. implemented several laws (e.g., Bayh-Dole Act) that changed patent practice (i.e., law) throughout the government (Heaton, 1989). During this period the United States undertook more aggressive methods of pursuing and enforcing patent infringement both in the U.S. and abroad. In 1982, Congress created the U.S. Court of Appeals for the Federal Circuit (CAFC) in Washington, DC to include a focus on patent-related cases. Decisions of the lower District Courts in cases involving patents can be appealed directly to the CAFC. The Omnibus Trade Act and Competitiveness Act of 1988 (P.L. 100-418) revised Article 37 of the United States Tariff Act of 1930; expanded the enforcement of process patents in the U.S. Patent Act of 1953, and instituted a "Special" Section 301 list that identifies countries not having adequate and effective protection of intellectual property rights that could subject them to trade sanctions by the United States. (These changes allow the U.S. to forbid the importation of goods solely on the basis of patent infringement, extend effective protection of process patent internationally, and generally broaden executive branch powers to enforce intellectual property rights.) Suits concerning patents filed in U.S. courts have more than doubled since 1980. Japanese companies have been particularly affected by U.S. government and American companies where substantial damages for patent infringement were awarded against Japanese-owned companies. Landmark cases include Honeywell Inc. v. Minolta Camera Co. Ltd. and Sanyo v. Texas Instruments.

A Japanese perspective. In Japan, patent rights are protected by the Patent Act of 1959, which has been frequently amended. Japanese patent law, first codified in 1895, was patterned after the German (Prussian) Code of Civil Procedure, but borrowed aspects from the French Civil Procedure. Although judicial precedent is considered, statutory law prevails. Administrative guidance and discretion influence decisions. The Japanese Patent Office (JPO) administers the examination and granting of patent rights in Japan. The JPO is an agency of MITI and is under the direct supervision of both MITIs Machinery and Information Industries and Trade Policy Bureaus. The Patent Commissioner is a senior, career MITI official appointed by the MITI Minister. After a two-to-three-year term, this official usually retires to a position as an advisor to private industry (Kotler and Hamilton, 1995).

In Japan, patents are regularly issued for what in the United States would be considered product line extensions. Upon filing, patents become a matter of public record. According to Herbig (1995), this provides more time to learn about the innovation; decide if its worth developing; and then replicate, circumvent, or ignore the patent. Competitors can file to delay the patent and then proceed to explore what is being patented. Unlike, in the United States, in Japan a family philosophy exists. An innovation does not exist merely for the inventor or inventing firm but for the benefit of the country as a whole. The entire Japanese patent system is aimed at avoiding conflict and promoting cooperation through cross-licensing (Melloan, 1988). Japan honors "first to apply," whereas the United States honors "first to invent." American patent applications must disclose all "prior art" thus proving that they have something distinctly new and different. Whereas the American system protects individuals, the Japanese system balances individual rights with broader social and industrial interests. There is a critical shortage of patent attorneys in Japan which helps explain that obtaining a patent in Japan takes considerably longer (four to six year versus two years) that it does in the U.S. As long as it is easier to copy under Japanese law, Japanese companies will continue to do so. Japan has been reluctant to tighten intellectual property laws, especially those concerning patents, believing that the country still

needs easy access to the creative ideas of the West, in particular those of United States (Herbig, 1995).

Recently, however, intellectual property issues have become an integral part of the bilateral economic discussions between the U.S. and Japan embodied in the *United States-Japan Framework for a New Economic Partnership*, better known as the "Framework Negotiations." Under the Framework initiated on July 10, 1993, Japan committed to achieving "tangible progress" toward market access and the use of objective criteria to assess implementation of the agreement. During 1994, two bilateral agreements were concluded under the Framework Working Group on Intellectual Property Rights. Under the first bilateral agreement (January 20, 1994), Japan agreed that patent applications could be filed in English and that translation errors could be corrected after patent issuance. The U.S. agreed to change the patent term to 20 years from the filing date instead of 17 years from grant date. Under the second bilateral agreement (August 16, 1994), the JPO agreed to introduce, by April 1, 1995, legislation to end the practice of allowing third parties to oppose a competitor's patent before it is granted and, by January 1, 1996, to put in place an accelerated patent examination procedure that will enable applicants to obtain disposition of their patent applications within 36 months, upon request; and by July 1, 1995, end the practice of awarding dependent patent compulsory licenses, which can force patent holders to license the use of their technology to competitors, thus limiting their exclusive rights to their inventions (Kotler and Hamilton, 1995).

Differences between the two systems. The U.S. and Japanese patent systems are shaped by fundamentally different purposes. In the United States, the patent system exists to provide an incentive for innovation by rewarding an inventor with the right to exclude others from practicing his or her invention. That reward is made in exchange for a full, complete, and enabling disclosure of the invention to the public. In contrast, the Japanese system focuses more on the goal of promoting Japanese industry and technological development by diffusing patent information through Japanese industry. The current system encourages corporate strategies that promote extensive filings, cross-licensing, and strategic filings. Public disclosure and long patent pendency is often used as a tool to dilute or prevent any reward to the inventor. In short, Japan interprets and uses its patent regime distinctively. Japan measures its rewards for invention in terms of social rather than individual benefits. (For greater detail concerning the differences between the two systems, see Kotler and Hamilton, 1995, pp. 25-36. Table 2, p. 37, contains the major differences between the U.S., Japanese, and European patent systems.)

The following section outlines the key differences between the U.S. and Japanese patent systems. In addition to the structural differences between the two patent systems, several aspects of patent practice and procedure differ between the United States and Japanese systems. The most obvious difference between the Japanese and U.S. systems is that the Japanese system, like that of most countries in the world, is a *first-to-file* system, whereas the U.S. system is a *first-to-invent* system. The first-to-file system entitles patent rights for the invention irrespective of whether that individual was, in fact, the first to invent the product, process, or design. This system promotes rapid filing of a large number of applications that can be prepared quickly, are narrow in scope, and often represent mere incremental advances. Another significant difference between the Japanese and U.S. patent systems is that Japan requires public disclosure of all patent applications within 18 months of filing. In the United States, applications are maintained in confidence up through the issue of the patent. In Japan, a patent takes an average of six to seven years to be issued compared to about 10 months in the United States.

There are substantially different legal bars to patentability between the United States and Japan. In the United States, a patent is barred if the invention is placed on sale, described in

printed publication, or publicly used more than one year prior to the application filing date. (If an application is filed within the grace period, however, such public disclosures are not necessarily fatal to obtaining a valid patent.) In Japan the grace period is shorter, only six months, and the set of circumstances in which the grace period applies is much more limited. Japanese law respecting public disclosures by use or sale also differs from that in the United States. In Japan, a disclosure must actually be made to the public to act as a bar and the set of events that may trigger a bar is narrower in Japan than in the United States. In the United States, a patentee may refuse to license other parties and the government can demand licensing only for limited reasons of national security. In contrast Japanese law allows interested parties to acquire a compulsory license to the patented invention in several circumstances. The Japanese patent system provides for *pre-grant* opposition to the award of patent rights. The JPO allows third parties to "oppose" or object to a pending patent application by submitting reasons why it should not be granted. The U.S. system allows no such provision.

Japanese patent applications must be filed in Japanese. In contrast, U.S. applications may be filed in a foreign (non-English) language as long as the initial foreign-language filing is followed within two months with a verified English-language translation. Each U.S. patent application is examined unless abandoned. In Japan, however, an applicant must specifically request examination and that request must be made within seven years of filing. Stringent U.S. Patent Office rules govern the duty to disclose information of which one is aware that is material to patentability. In Japan, there is no similar duty. Finally, unlike in the United States, a challenge to a patent's validity is not brought before the courts, but instead directly to the JPO.

A REVIEW OF THE JAPANESE AIRCRAFT INDUSTRY

Our review of the Japanese aircraft industry is brief. Designed to establish a contemporary (i.e., World War II to 1996) perspective, it is not comprehensive and only partially analytical; we have left that task to others. (See, for example, Barber and Scott, 1995; Council on Competitiveness, 1996; Cravens, Kirk, Downey, and Lauritano, 1992; Frenkel, 1984; Friedman and Samuels, 1993); Johnson, Tyson, and Zysman, 1989; Lopez and Herzfeld, 1991; Moran and Mowery, 1994; Mowery, 1990, 1987; Mowery and Rosenberg, 1985a, 1985b; Mowery and Teece, 1993; Moxon, Gerginger, and Michael, 1985; National Research Council, 1994; Roehl and Truitt, 1987; Sabbagh, 1996; Samuels and Whipple, 1989a; Schwartz, 1996; Todd and Simpson, 1986; U.S. Congress, Office of Technology Assessment, 1991; Yoshino, 1986.) Todd and Simpson (1986) indicate that the international economic system, of which Japan is apart, is characterized by at least three important tendencies—(a) the concentration of political, economic, and military power; (b) the transnationalization (i.e., globalization) of markets, production, and finance; and (c) the importance of control over technology. The latter is essential to the accumulation and retention of political, economic, and military power and for states to position themselves in a global economy. Consequently, states, especially those with capitalist economies such as Japan, "intervene" in the market by developing industrial policies and strategies designed to strengthen and expand their competitive positions in the international, global economy.

Together with fiscal and monetary policies and strategies, industrial policies and strategies constitute one element of a nation's basic economic structure. Countries like Japan employ a variety of public policies and strategies to facilitate the development of industries (and firms) that are at the forefront of technological development. A salient feature of these policies and strategies has been to "target" certain high technology industries and firms as "recipients of special state attention and largesse" (Todd and Simpson, 1986, p. 209). They are almost always "knowledge-intensive" industries that generate a substantial multiplier or spill-over of adaptable knowledge

for use by other industries. Aircraft production is one such industry. Japan has targeted the aircraft industry as one of three key technologies for the twenty-first century. Government support for this industry, one in a long succession of targeted industries, is seen by Japan as another step up the technological ladder (U.S. Congress, Office of Technology Assessment, 1991).

Coveted for its knowledge and technological linkages to a variety of other high-value added industries, aeronautical R&D is viewed by MITI as a knowledge-intensive endeavor, the results of which are applicable and can be "spun on" to a wide range of disciplines and industries (Figure 1). Progress in aeronautics can promote advancements in a number of technologies, and it is critical for the development of technologically-oriented societies like Japan's. The government of Japan believes that aircraft production provides knowledge and technology that complement Japan's strengths in such areas as materials, microelectronics, and computer-aided design and manufacturing (CAD/CAM) (Mowery and Rosenberg, 1985b). In targeting aircraft production, MITI has selected an industry where, from a long-range point of view, income elasticity of demand is high, technological progress is rapid, and labor productivity rises fast. With World War II as a backdrop, three aspects of Japan's efforts to build an aircraft industry—importation of U.S. (military) aeronautical technology, indigenous production, and international collaboration—are profiled.

An indigenous Japanese aircraft industry existed prior to World War II (Samuels, 1994, Chapter 4). It became the largest and the most technologically sophisticated in the world during World War II. During the peak period of wartime production, the Japanese aircraft industry was producing 25 000 airframes and 40 000 engines per year (Mowery, 1990). The same Japanese companies that produced aircraft also produced a number of military and non-military products. (Diversity is a hallmark of Japanese industrial policy.) Japan's pre-World War II industry was (a) promoted for national purposes; (b) organized to import, absorb, and apply external knowledge

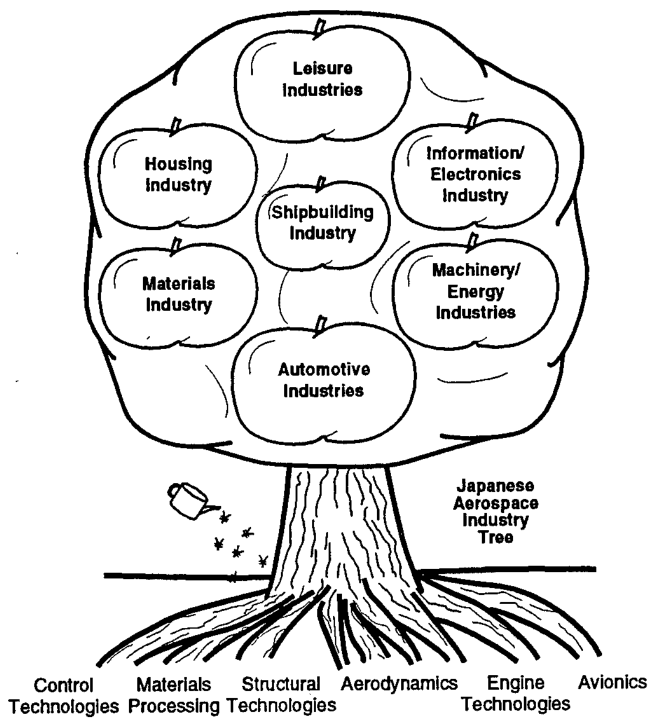

Figure 1. Japanese Technology Spin on Model.

and technology; and (c) focused on developing a domestic product-manufacturing capability (National Research Council, 1994). In 1945, the Supreme Commander for the Allied Powers (SCAP) dissolved the Japanese aircraft industry, prohibited the production of aircraft, and dismantled the aircraft firms that had been consolidated between 1928 and 1937 (Mowery, 1987). All flights of Japanese aircraft ceased. American occupational forces took over all aircraft production facilities. In August 1945, the SCAP unveiled a program to destroy all military and civilian aircraft before the end of the year. In November, the Imperial Japanese government was instructed to abolish all governmental and semi-governmental bodies concerned with aviation. The RD&P of all aircraft and components, even for model airplanes, was banned (Samuels, 1994).

Importation of U.S. (Military) Aeronautical Technology

The end of the military occupation of Japan by the SCAP effectively removed the prohibition on aircraft production. The outbreak of the Korean War in 1950 accelerated the reemergence of the Japanese aircraft industry. With the signing of a U.S.-Japanese treaty in 1952, the ban on aircraft production was formally lifted. By 1953, Japanese industry had orders for more than two million manhours of overhaul and aircraft repair work for the U.S. military. Showa Aircraft received the contract to overhaul U.S. Navy fighter planes, trainers, and transports. Kawasaki received a similar contract from the U.S. Air Force that same year. In 1953, Mitsubishi received the contract to overhaul B-26 bombers. By 1955, Japanese industry was repairing and overhauling all U.S. Navy aircraft in the Far East. This activity provided an essential "learning-by-doing" experience, a critical first step in rebuilding the Japanese aircraft industry.

In July 1954, the Japanese Diet enacted the Aircraft Manufacturing Enterprises Law, which controlled entry into the industry, allowed industry-wide collaboration, exempted aircraft manufacturers from the country's antimonopoly laws, and otherwise provided the foundation for future aircraft production (Frenkel, 1984). Most importantly, the law gave MITI jurisdiction over the aircraft industry. In 1958, Japan entered another stage in the development of its aircraft industry with the passage of the Aircraft Industry Promotion Law (Todd and Simpson, 1986). This law established the Nippon Aircraft Manufacturing Company (a consortium of Mitsubishi Heavy Industries, Kawasaki Heavy Industries, Fuji Heavy Industries, Showa Aircraft, Japan Aircraft, and Shin Meiwa Industries), a 50-50 joint venture of private and public interests, with the government bearing the financial risks and providing liberalized investment and depreciation credits (Mowery, 1990). The law also laid the foundation for the development of the YS-11, a medium-size turboprop commercial aircraft (Frenkel, 1984).

MITI's role in industrial policy encompasses stabilizing markets, nurturing domestic producers, and acquiring (importing) and diffusing technology. To reestablish Japan's aircraft industry, MITI decided to acquire the requisite advanced technology through the licensed production of U.S. military aircraft. Eager to oblige its most important Pacific ally, the U.S. Department of Defense (DoD) willingly helped Japan undertake the production of military aircraft. In 1954, the United States and Japan signed the Mutual Defense Assistance Act. The treaty provided for licensed Japanese production of U.S. military aircraft for the Japanese Self Defense Force. That same year, the U.S. DoD formally requested and provided subsidies for Japan to undertake the licensed production of two U.S. military aircraft, the F-86 and the T-33. Under this agreement, all production and design know-how was transferred to Japan. Furthermore, Japanese manufacturers were allowed to produce up to 50% the aircraft's content domestically. In 1957, Kawasaki was awarded a license to produce the Lockheed P2V-7 antisubmarine/ search aircraft with 50% Japanese content. Shin Mitsubishi Heavy Industries was permitted in 1958 to co-produce Lockheed's F-104, with the United States agreeing to pay $75 million, more than a quarter of the total cost (Hall and Johnson, 1970). The license to produce the F-104's engines (General Electric's J-79) was awarded to Ishikawajima-Harima Heavy Industries. In 1968, the

Japan Defense Industry selected the McDonnell Douglas F-4 as Japan's new frontline fighter. Mitsubishi Heavy Industries was granted a license to produce the aircraft (i.e., the Mitsubishi F-1) and served as the prime contractor for the project. More than 70 Japanese firms participated in the project, including Japan's leading electronics firms. Although the F-1 failed to meet any credible military purpose, it was a policy success in terms of domestic content (imported parts comprised less than 2% of the total aircraft), learning-by-doing, and technology diffusion (Samuels, 1994).

In 1970, the Japan Defense Agency indicated its intention to develop an indigenous (i.e., domestically produced) antisubmarine warfare aircraft rather than importing Lockheed's P-3C, the most advanced airborne antisubmarine warfare system available. A combination of Japanese domestic politics and pressure from the United States over an increasing U.S.-Japan trade deficit produced a decision to purchase the Lockheed P-3C Orion, but only if a Japanese firm participated in the aircraft's licensed production. Kawasaki Heavy Industries served as the prime contractor for the project that included nearly 3000 Japanese firms as subcontractors. Japan's domestic content was twice that contained in the P2-J, the aircraft being replaced. The electronic components were licensed separately from Lockheed's suppliers. In 1974, the Japan Defense Agency announced its plans to replace its aging F-104 frontline interceptor. Again the choice was indigenous development or licensed co-production. The candidates for foreign (i.e., U.S.) co-production included McDonnell Douglas's F-15, General Dynamics' F-16, Grumman' F-14, and Northrop's F-17 (later the F-18). By now it was clear to most everyone following Japanese industrial policy that Japan was openingly pursuing aerospace as much to enhance the industry's technology base as to protect the nation (Frenkel, 1984). In December 1977, the Japan Self Defense Agency selected McDonnell Douglas's F-15 as Japan's frontline interceptor.

As Samuels (1994) points out, the F-15 is a Mach 2.5 advanced fighter aircraft that carries some of the most advanced avionics and weapons systems in the U.S. arsenal. Prior to 1974, the United States was still willing to license aeronautical technology to Japan. However, for the first time, transferring state-of-the-art aeronautical technology from the United States to Japan became an issue. Not only was the United States willing to transfer state-of-the-art aeronautical technology for reasons of national security, but it was also willing (for the first time) to co-produce an advanced fighter aircraft *before its first upgrade*. According the Chinworth (1992, p. 92), "economic concerns were being subjugated to the perceived need of retaining balance in the political relationship because of Japan's strategic position." In June 1978, the United States and Japan signed a Memorandum of Understanding (MOU) that established clear limits on the transfer of technology. The MOU reduced the percentage of Japan's domestic content to about 55%, declared certain technology to be "unreleasable," and contained provisions for deriving "flowback" of technology to the United States. The Japanese benefitted considerably from the agreement. The F-15 co-production transferred more technology to Japan than any previous co-production project, including such capabilities as composite material processing and bonding, a full range of avionics and flight software, and fly-by-wire integration. Chinworth (1992) reported that some of the licensed U.S. technology was used by the Japanese to compete with the original licensor (e.g., Honeywell) in overseas and U.S markets, including component suppliers to Boeing's civil aircraft programs. A U.S. Congress, General Accounting Office (GAO) (1992) report indicates that considerable knowledge and technology acquired from the project was successfully diffused to several non-aerospace Japanese industries.

In July 1982, Japan's National Defense Council approved funds in their 1981-1986 five-year plan to purchase 24 Fighter Support-Experimental (FS-X) aircraft. The justification for the new aircraft was twofold: after 1981, Japan assumed the responsibility for protecting its territory, airspace, and sea lanes out to 1000 miles, and Japan's heavy industry companies needed new

aircraft projects badly to utilize depressed shipyard and other heavy industry capacity. According to Samuels (1994), the FS-X was born of both military threat and the need to nurture domestic industry. To MITI and the Japanese aircraft industry, the FS-X represented the long awaited opportunity to acquire the RD&P needed to create a state-of-the-art, indigenous "Rising Sun" fighter aircraft. However, technical (e.g., avionics) and structural (e.g., metal fatigue) obsolescence was driving the need to replace both the F-1 and the F-4, and many observers believed that Japan had neither the technical expertise nor the financial resources to build a first-rate, indigenous jet fighter. U.S. observers concluded that the timetable did not allow enough time for indigenous development and, consequently, Japan would ultimately settle on co-production or purchase of a U.S. fighter. On the other hand, if Japan chose indigenous development, the U.S. aircraft industry would provide certain components, most likely the engines. To the surprise of some observers, Japan embarked on a Service Life Extension Program (SLIP) that involved reinforcing and refitting the F-4EJ with advanced avionics and armaments. The SLIP concept and the technology were imported from the U.S. where such programs were commonplace in the defense industry. In 1984, Japan announced that the F-4EJ would last another five years. The SLIP gave something to everyone. Japan received additional time for indigenous development, the avionics were purchased from U.S. producers, Mitsubishi Heavy Industries obtained experience integrating digital avionics, and funding for an indigenous "Rising Sun" fighter aircraft was delayed (Samuels, 1994).

Japan now had four choices: (a) indigenous development, (b) reconfiguration of an existing aircraft, (c) co-production or co-development of an aircraft, and (d) purchase an existing (i.e., off-the-shelf) foreign aircraft. Japanese politics favored indigenous development; however, neither the U.S. government nor the U.S. aircraft industry was anxious for Japan to develop an indigenous fighter. In 1985, the U.S. formally took up the issue and pushed for another co-production or co-development program. By 1987, the U.S. Congress turned its attention to the FS-X issue. Owing largely to an increasing trade deficit and the illegal sale by Toshiba of milling equipment to the Soviets, Japan's proposal for co-development of a completely new FS-X was rejected. In October 1987, Japan announced that a "lightly modified" U.S. aircraft, either the F-15 or F-16, would be procured. The F-16, which offered the most room for applying indigenous Japanese aeronautical technology, was selected. A June 1988 MOU stated that General Dynamics would furnish F-16 technology and assist in systems integration and, in return, General Dynamics would have access to all technology brought to the project by the Japanese. The FS-X MOU also contained a set of rules governing the transfer of knowledge and technology: Japan received access to some of the United States' most sophisticated aeronautical technology. In return, the Japanese agreed to return any improvements they made at no charge and without being asked, and if asked and paid, they would make available any original (i.e., nonderived) Japanese technology used in the program. They also agreed to make an exception to Japanese patent law: U.S. aircraft firms could have military patents held confidentially at the Japanese Defense Agency instead of openly at MITI (Samuels, 1994). The MOU also specified that 40% of the engines would be U.S.–manufactured. General Electric was selected over Pratt & Whitney and agreed, as a condition of sale, that Isikawajima-Harima Heavy Industries would produce more than 50% of the engines under license in Japan (Samuels and Whipple, 1989b).

The FS-X project would serve the interests of both countries: Japanese knowledge and technology would improve U.S. fighter aircraft capabilities and Japan would receive U.S. assistance in the design and development of an advanced jet fighter. U.S. critics of the FS-X project viewed co-production as the next stage in the process of (Japanese) indigenous production and an important step in their development as a world class (civil) aircraft industry. Japanese critics were convinced that the United States was participating in the FS-X project simply to improve (at Japanese expense) the capability of its fighter aircraft and that the United States would be acquiring knowledge and technology paid for by the Japanese. A skeptical U.S. Congress

viewed the FS-X project in the broader context of trade and economic policy, held hearings, and demanded an interagency (i.e., Commerce, Defense, and Trade) review of the MOU (Shear, 1994). The U.S. and Japan signed a "clarified" MOU in April 1990 that reportedly contained many of the terms included in the original agreement, reaffirmed the workshare percentages, and denied Japan access to flight control source codes having direct commercial application. In October 1992, an agreement for co-production of flight control software between Bendix Corporation and Japan Aviation Electronics was signed (Samuels, 1994).

Indigenous Production

The strategic vision of an indigenous aircraft industry was shared by MITI and Japan's heavy industries. The vision was one of an indigenous aircraft industry that would rest on the shoulders of Japan's already established manufacturing industries (Samuels and Whipple, 1989). As the aircraft industry grew in size and technical sophistication, the resulting knowledge and technology would diffuse throughout Japan's manufacturing industries. The strategy was simple: create an indigenous aircraft industry by developing a coordinated group of Japanese aircraft manufacturers that could collaborate and share (explicit and tacit) knowledge and technology. Careful project selection would raise the competence and capability of Japanese aircraft manufacturers in airframe, engine, and avionics technologies. As part of the strategy, knowledge and technology imported through the co-production of military aircraft and from indigenous production would diffuse throughout the firm, to other Japanese aircraft manufacturers, and to other Japanese industries. Scholars generally agree that this strategy dramatically increased the capability and technical sophistication of Japan's aircraft manufacturers and that other Japanese industries have benefitted significantly from the knowledge and technology derived from aircraft production. Four indigenous aircraft projects—the YS-11, PS-1, T-2 Trainer, and the J3 turbojet engine—demonstrate the strategy's effectiveness.

YS-11. The passage of the Second Aircraft Promotion Law in 1958 established the policy framework for the development of an indigenous Japanese commercial aircraft industry, laid the foundation for the production of the YS-11, (Japan's first indigenous commercial transport of the postwar era), and authorized MITI to provide 54% of the RD&P costs for development of the YS-11. According to Samuels (1994), the YS-11 was not about becoming a power in commercial aviation; it was about catching up and surpassing other industrial nations by improving Japan's balance of trade and enhancing the technological capabilities of its heavy industries. The RD&P of the YS-11, a 64-seat turboprop commercial aircraft, was a collaborative undertaking involving the Nippon Airplane Manufacturing Company (a national policy company), six manufacturing partners, and dozens of component suppliers. According to the plan, the engines would be purchased from Rolls-Royce and 150 aircraft would be produced between 1963 and 1970. The YS-11 was introduced in 1962; in all, 182 aircraft were sold before production ceased in 1970 (Yoshino, 1986). The YS-11 was a technical success, but it was an economic failure. The technical success was due in part to the concurrent activities of Japanese industry throughout the 1950s and 1960s, producing military aircraft under license to U.S. producers. For example, the landing gear on the YS-11 was adapted from the one used on the P2V-7, a military aircraft co-produced by Kawasaki Heavy Industries and Lockheed. However, financial considerations, problems internal to the collaborative arrangement, a limited market for a 64-seat turbo-prop commercial aircraft, competition from established aircraft firms (e.g., Fokker), the successful introduction of commercial jet aircraft, and a lack of experience in marketing and sales helped to make the YS-11 a market (commercial) failure (Frenkel, 1984). The Japanese experience with the YS-11 was similar to that experienced by the Europeans as they sought to restructure and rebuild their LCA industry (see Chapter 17). The Japanese encountered similar obstacles, learned similar lessons,

and, like the Europeans, continued to focus on industry collaboration and the establishment of an indigenous aircraft industry as a strategic source of knowledge and technology.

PS-1. Japan's second indigenous project was the P-1 antisubmarine warfare plane designed and manufactured by Shin Meiwa. Although there is some disagreement about the extent to which Shin Meiwa borrowed from the Grumman HU-16 Albatross, there is no dispute about the technological success of the aircraft. The Japanese hailed the PS-1 as a major breakthrough in short take-off and landing technology and as a shining example of collaboration among Japan's aircraft manufacturers, subcontractors, and suppliers. Shin Meiwa derived enormous advantage for its commercial businesses. Knowledge and technology acquired from the PS-1 were applied to hydraulic equipment, auto engine controllers, automatic machinery, and the welding of exotic metals. Lastly, the PS-1 "wave suppressing" sonar, Japan's first post war aircraft technology export, was licensed to Martin and Grumman (Samuels, 1994).

T-2 Trainer. Successor to the T-1, the T-2 was a product of industrial policy. Indigenous production of the T-2 had little to do with military roles and missions. The T-2 provided Japanese aircraft manufacturers with valuable independent design, development, and systems integration experience. It also helped establish Japanese competence in supersonic airframes and avionics, and it served as the basis for developing Japan's first supersonic jet fighter, the F-1. As with virtually all of the co-production work undertaken by Japanese aircraft manufacturers, the T-2 was a collaborative undertaking. The Adour engine, a product of a joint venture involving Rolls-Royce and Turbomeca, was selected to power the T-2, a point to which we will return shortly. The T-2 would not have been possible without the considerable knowledge, technology, and learning-by-doing and learning-by using experience garnered from co-producing such U.S. military aircraft as Lock-heed's T-33 trainer. Co-production usually included the transfer of data packages that incorporated product designs and specifications, process specifications, tools or tool specifications, and often included "knock-down" kits of the aircraft being co-produced (i.e., assembled). The T-2 is significant for two reasons: it helped Japanese aircraft manufacturers establish the RD&P necessary to produce a supersonic jet fighter, the F-1, and it generated considerable knowledge, technology, and experience that was applied to other Japanese industries (Samuels, 1994).

J3 Turbojet Engine. The Adour engine was selected to power the T-2 because, from the Japanese perspective, it provided access to an entirely different design configuration from that found in U.S. made jet engines. However, according to Samuels (1994), the Adour was not the abundant source of technology originally envisioned by he Japanese. Consequently, the Japanese redoubled their efforts to develop indigenous jet engine technology. It is worth noting that Japanese aircraft engine development is a product of MITI industrial policy that began with the creation of a collaborative (industry) study group in 1953. Working closely with the U.S. DoD, MITI arranged for the U.S. Air Force to invite Japanese engineers to tour the facilities of aircraft engine manufacturers in the U.S. and to have access to the technical reports produced by the (U.S.) National Advisory Committee for Aeronautics (NACA). The U.S. Air Force provided a working Allison J-33 jet engine and an engineer from Allison for one year, free of charge. Detailed instructions, blueprints, the operator's manual, detailed sketches of production tools and jigs, and tools were also provided to the Japanese. In 1953, the Japan Jet Engine (Consortium) Company was formed to create and deliver to MITI the JO-1 engine.

The JO-1 was heavier and noisier that the J-33 and never powered an airplane. However, having access to and considerable experience with (repairing and maintaining) U.S. military engines, the consortium was convinced that it could become "a player in the market" for military jet engines. Plans for a (three-ton) J-1 were declared by MITI to be "overly" ambitious and the consortium switched to a smaller J-2 engine that never went beyond the drawing board. Rather

than license a foreign engine, the consortium was given yet another "opportunity to learn," and, in October 1956, the consortium delivered three (prototype) J-3 engines. However, the engines could not be produced in time to power the T-1 trainer. Consequently 20 jet engines were purchased from the U.K. Completed J-3 engines were eventually fitted to T-1 trainers and were later adopted as a booster engine for the P2J aircraft.

As with other aircraft projects undertaken by Japan, the lessons learned from producing jet engines were substantial. Japanese aircraft manufacturers learned that aircraft engines are more difficult and take longer to develop than do airframes, producing engines involves tremendous opportunity costs, and access to foreign (engine) knowledge and technology was essential if Japan were to develop an indigenous aircraft engine capability. Finally, as with other indigenous aircraft projects, substantial amounts of knowledge, technology, and experience were applied to other Japanese industries.

International Collaboration

Early in the 1980s, MITI, in its *Vision of Industrial Structure for the 1980s*, identified LCA as a key Japanese industry for the 1990s. Four attributes make LCA production desirable—high value-added characteristics, minimal environmental pollution, high knowledge intensity, and linkages between aircraft and other high technology industries (Mowery, 1990). It is important to note that MITI focused on LCA production and *not* on the production of commuter and general aviation aircraft and helicopters. (Although LCA became MITI's focus, Japanese aircraft manufacturers remain in the business of producing general aviation aircraft and helicopters.) MITI reasoned that the knowledge, technology, and production skills and techniques involved in LCA production are of such sophistication as to ensure Japan's technological lead in the industry. The ministry further reasoned that such sophistication could be used to establish and maintain existing strategic alliances and technology linkages between the aircraft and other Japanese high technology industries. Finally, from military co-production and the YS-11 experience, MITI concluded four things. *First*, the market, both domestic and foreign, for military aircraft was relatively small, cyclic, and well established. *Second*, the small size of the domestic (Japanese) market (coupled with the lack of a mechanism for international sales and a launch customer) was insufficient to support commercial aircraft production. *Third*, the RD&P costs are so great that no one firm (or consortium of Japanese firms) can assume the risk associated with launching a new LCA. *Fourth*, Japanese industrial policies, industry structure, and airframe and engine consortia combine to make Japan ideally suited to participate in joint ventures as subcontractors and risk-sharing partners with established LCA producers (e.g., Boeing). Participation in joint ventures offered the best opportunity for Japan to participate in the research, development, production, and marketing of LCA (Mowery, 1987).

The four Japanese heavy industry companies—Fuji, Ishikawajima-Harima, Kawasaki, and Mitsubishi—became subcontractors to U.S. LCA producers. Fuji manufactured rudders for the Boeing 747. Kawasaki produced entry doors for the Lockheed-1011, outer trailing-edge flaps for the Boeing 747, actuator transmissions for the Boeing 727, and inner flaps and wing ribs for the Boeing 737. Mitsubishi built engine transport kits for the Boeing 757 and inner trailing-edge flaps for the Boeing 747 and assembled tail cones for the McDonnell Douglas DC-10. MITI established the Japanese Aircraft Development Fund (JADC) in 1986 to support Japanese participation in new international LCA programs. The JADC reflects MITIs decision in the 1980s to foster international collaboration as the major mechanism for strengthening Japan's domestic aircraft industry (National Research Council, 1994). The JADC made it possible for Japanese companies to become risk-sharing partners with Boeing in developing the 777.

The RD&P of an LCA is a high-risk venture compounded by technical and marketplace uncertainty. The Boeing 777 is no exception. The RD&P of the 777 cost the Boeing company more than $ 5 billion. The unit (per plane) cost approximates $150 million. The Boeing 777 has more than 3 million parts, 132 500 of which require sophisticated engineering. The economics of LCA production pushes companies like Boeing to form international alliances and linkages to share risks (National Academy Press, 1994; Golich, 1992). A notable feature of the Boeing 777 is its substantial international component, including the outsourcing of certain production-related activities and components. About 15-20% of the components are foreign-made (Figure 2) (Schwartz, 1996). The JADC, a consortium of the three largest Japanese manufacturers, provides about 21% of the aircraft's frame, or 10% of the overall plane. MITI provided $18.2 million, in the form of low-cost loans for the nonrecurring costs, to support JADC's participation in the Boeing 777 project. The Japanese Development Bank allocated $31.1 billion to finance Japanese involvement in the B-777 and two other ventures (Council on Competitiveness, 1996).

Engine (propulsion) is a key enabling technology underlying LCA production. Substantial technical and marketplace uncertainty is associated with the production of jet engines for LCA. The economics (i.e., capital and risk) involved in the production of LCA engines pushes companies to form international alliance and linkages to share risk and to gain market entry. The two U.S. manufacturers of jet engines for LCA—GE Aircraft Engines and Pratt & Whitney (a division of United Technologies)—have extensive, long-standing alliances and linkages with Japan (National Academy Press, 1994). For example, International Aero Engines, which produces the V2500 jet engine, includes Pratt & Whitney, Rolls-Royce, Fiat, MTU, Ishikawajima-Harima, Kawasaki, and Mitsubishi in what Mowery (1994) describes as one of the most complex joint ventures in the LCA industry. GE, whose association with Japan in engine technology dates back to the 1950s, collaborates with Ishikawajima-Harima in the development of the GE90 engine. (The GE90 is the first of what GE hopes to be a new family of large engines for LCA). In addition to Ishikawajima-Harima, which has an 8% share in the program, SNECMA (France) holds a 25% share, and Fiat (Italy) holds an 8% share. Both GE and Pratt & Whitney participate in the Japanese

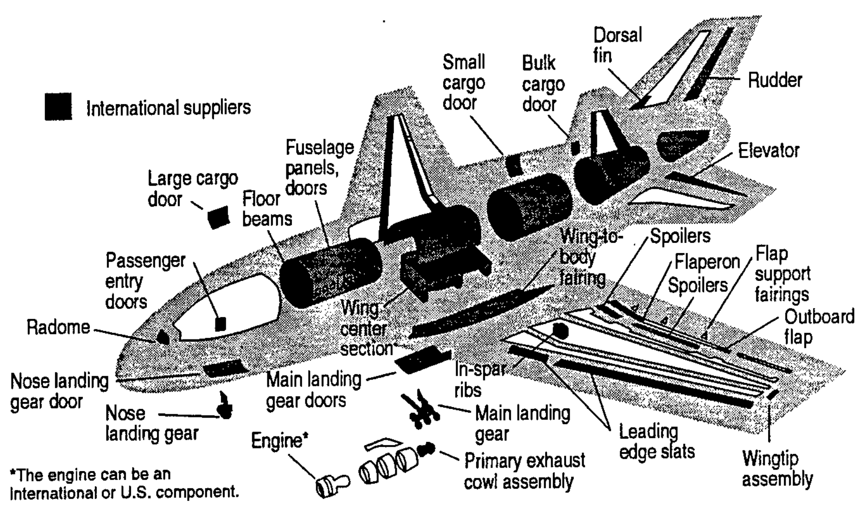

Figure 2. The Internationalization of the Boeing 777.

Supersonic/Hypersonic Propulsion Technology Program (JSPTP or HYPR). The ultimate program goal is the development of a scale prototype turbo ramjet, Mach 5, methane-fueled engine. Finally, Mowery (1994) notes that up to now, the risk and cost of LCA engine development could be reduced by applying the often substantial amount of "spill-over" or dual-use knowledge and technology derived from the development of engines for military aircraft.

STRATEGIC ALLIANCES AND TECHNOLOGY LINKAGES

The globalization of knowledge and technology has contributed to the creation of a global economy (Levitt, 1988). Badaracco (1991) makes four points about the globalization of knowledge (and technology)—(a) the pool of available knowledge (and technology) is increasing as developed and developing countries devote more of their resources to the creation of knowledge; (b) worldwide, the number of organizations and individuals producing, transferring, and using knowledge is increasing; (c) global transportation, access to, and improvements in communications combine to hasten the portability of knowledge; and (d) firms are creating alliances and linkages as a means of accessing (importing) external sources of knowledge and technology. A firm's ability to recognize the value of external knowledge and technology, assimilate, absorb, and apply them for commercial purposes is critical to its innovative capability (Cohen and Levinthal, 1990). The importation of knowledge and technology is a hallmark of post World War II Japan. At the national and organizational levels, public policy and numerous alliances and linkages are used by the Japanese to import knowledge and technology worldwide (Peck and Goto, 1981; Smitka, 1991). Competitively, this is important, considering the inability of the United States to match Japan as a quick and effective user of external knowledge and technology (i.e., using knowledge and technology developed outside of the innovating firm) (Mansfield, 1988).

Background

Competitiveness is a function of a firm's ability to innovate quickly and efficiently. Against a backdrop of intense global competition, increasing costs of producing knowledge and technology (internally), and dramatic reductions in product life cycles, make a firm's ability to create and apply knowledge and technology all the more important. This is very important in such knowledge-intensive industries as aerospace. Intensive global competition has given rise to the creation of national and transnational alliances and linkages (e.g., joint ventures and license agreements) as a means of obtaining (external) knowledge and technology (Killing, 1980; Merifield, 1989; Ohmae, 1989; Ouchi and Bolton, 1988). Badaracco (1991) states that neither alliances nor knowledge-based competition is new. Alliances between nations for protection and trade have existed for centuries. What is new is the way in which alliances and linkages are changing competition in the global marketplace (Lewis, 1995). Simply put, an alliance is a partnership that enhances the competitive strategy or position of two or more firms by providing for their mutual benefit access to explicit and tacit knowledge, technologies, skills, products, processes, or materials (Pister, 1988).

Yoshino and Rangan (1995) define a strategic alliance as possessing simultaneously the following three *necessary* and *sufficient* characteristics: (a) the two or more firms that unite to pursue a set of agreed upon goals remain independent subsequent to the formation of the alliance, (b) the partner firms share the benefits of the alliance and control over the performance of assigned tasks (perhaps the most distinctive characteristic of alliances and the one that makes them so difficult to manage), and (c) the partner firms contribute on a continuing basis in one or more key strategic areas. Alliances and linkages are formed for a multitude of reasons that include securing capital, obtaining market access and increasing market share, lowering risks and

costs, and gaining access to and creating new knowledge and technology. Leonard-Barton (1995) states that companies usually create alliances for one of two reasons—to forestall a competitor's partnership with the targeted ally or to plug a hole in their own knowledge or technological capability. Further, she notes three types of alliances: *supply*, which are formed to minimize the cost of trade and product exchange; *positioning*, which help firms create or overcome market entry barriers; and *learning*, which are used to augment internal knowledge.

The use of alliances and linkages to access or acquire external knowledge and technology may take the form of a "multiplicity of relationships" (Leonard-Barton, 1995) including licensing, co-development, joint ventures and programs, mergers, and participation in R&D and research consortia. Collaboration among competitors for the production and sharing of knowledge and technology has a rather long history in Japan, although it is a relatively new development in the U.S. Alliances among U.S. firms competing in the same product markets have been limited by legal proscriptions. Changes in the antitrust provisions of the U.S. Code in the late 1970s now permit R&D collaborative ventures among competitors. Passage of the National Cooperative Research Act (P.L. 98-462) gave rise to such U.S. research consortia as the Semiconductor Research Corporation (SRC), the Microelectronics and Computer Corporation (MCC), and Sematech (Heaton, 1989; 1988).

Japanese and U.S. Alliances and Linkages in Biotechnology and Semiconductors

Alliances and linkages, in the form of interfirm research collaboration, are widespread, structurally diverse, and increasing rapidly in Japan. In fact, collaboration is the defining feature of Japanese research and is commonplace in Japanese knowledge-intensive industries. A study by Niwa and Goto (1993) bears this out. The results show that (a) R&D collaboration in Japan has increased and will increase in the future; (b) collaboration is undertaken to economize R&D resources and to reinforce technological potential based on synergy effects; (c) a variety of relationships is involved and differs according to industry type; (d) the goals, management strategies, and outcomes were clearly established and agreed to by the participants; and (e) there was a strong international component in many of the collaborative efforts.

We now focus on the international aspects of Japanese and U.S. alliances and linkages in two areas—*biotechnology* and *semiconductors* and two studies conducted by the National Research Council. These studies examined the scope and nature of alliances and linkages between the U.S. and Japan, the forces behind these linkages, and their impact on the future competitiveness of the U.S. in bio-technology and semiconductors (National Research Council, 1992b and 1992a).

Biotechnology. The U.S. is a world leader in biotechnology. Biotechnology and the pharmaceutical industry have been rated second to computer software and related services in terms of their total value creation among U.S. knowledge-intensive companies created since 1965. Likewise, government and industry in Japan have identified biotechnology as a key technology for future industrial growth and are working together to increase R&D investment in this field. Furthermore, Japan, as a matter of public policy, emphasizes technological commercialization, and uses alliances and linkages with firms and institutions in several countries, in particular the U.S., to import, absorb, and diffuse knowledge and technology. Finally, it is important to remember that, as they do in other disciplines, Japan and large Japanese firms invest substantial resources in competitive intelligence—collecting the world's scientific literature, attending conferences and symposia, following the work of the world's leading biotechnology researchers, monitoring U.S. patent registration activities, and visiting U.S. universities and national research laboratories (National Research Council, 1992b).

Biotechnology is a research- and capital-intensive industry, which involves many scientific disciplines and for which intellectual property rights protection and government regulations are critically important. Foreign investment, particularly Japanese investment, plays a major role in U.S. and European biotechnology industries. Alliances and linkages in biotechnology include company-to-company and company-to-universities, -national research laboratories, and -biotechnology center activities. Increased competition and co-operation between the U.S. and Japan is inevitable as biotechnology becomes part of an increasingly global economy and technology base. Alliances and linkages between U.S. and Japanese firms in biotechnology are complex, involve various mechanisms, and reflect the structural characteristics of biotechnology in the two countries. From the U.S. perspective, many of the U.S. biotechnology firms are small; hence, the need of these firms for capital to conduct R&D and the attraction of large, capital rich Japanese pharmaceutical companies. Furthermore, large U.S. pharmaceutical companies and biotechnology firms seek market access to Japan. For the Japanese, biotechnology is a technological tool that permits diversification into new, higher value-added product areas. Japanese firms also view biotechnology as a way to allocate scarce resources to improve their productivity and international competitiveness (National Research Council, 1992b).

Alliances and linkages are important because they present an opportunity for the two-way flow of knowledge and technology. Some involve the commercialization of existing technology and some are established for developing new technology. How they are structured, organized, and managed will determine, in large part, how much knowledge and technology actually flow from Japan to the U.S. Two findings of the National Research Council (1992b) study are significant. *First*, the study found a prevailing pattern of the transfer of biotechnology developed in the U.S to Japan during the past two decades. *Second*, regarding alliances and linkages, the predominant flow of knowledge and technology is and continues to be in the direction from the United States to Japan. For example, the study found that (a) Japanese firms are increasing their ties to U.S. colleges and universities by endowing chairs, providing institutional grants, contracting with faculty, and educating Japanese students in the U.S.; (b) the number of Japanese conducting research in biotechnology and related areas in the U.S. far exceeds the number of U.S. researchers doing biotechnology and related research in Japan; (c) annually, the number of Japanese researchers visiting U.S. biotechnology centers far exceeds the number of researchers from the U.S. who visit Japanese biotechnology centers; and (d) although there has been an increase in the number of alliances between and among U.S. biotechnology firms, three times as many company-to-company linkages were formed between Japanese and U.S. companies as were formed between U.S. and Japanese companies. These findings led the National Research Council (1992b) to conclude that:

> Looking at past patterns, some wonder whether U.S. firms can develop effective strategies for making [knowledge and technology] alliances and linkages with Japan work to their advantage in the future. (pp. 2-3)

Semiconductors. Japan and the United States are the world's largest producers of semiconductors. Semiconductors, which are strategically crucial to national defense, are critical components of the electronics and communications industries and are vital to the economies of both countries. Alliances and linkages between U.S. and Japanese firms have long played a major role in the development and diffusion of technology and have helped shape the competitive landscape of the semiconductor industry. From the U.S. perspective, Japanese companies often provide American start-up companies with needed venture capital and offer large U.S. companies access to advanced manufacturing capability and the rapidly growing Japanese market. Small U.S. firms provide access to complementary technical capabilities that can be leveraged to obtain a stronger position, which can then be used to obtain a strong position in the new, design-intensive semiconductor markets. The National Research Council (1992a) study takes the position that, in the short term, alliances and linkages have facilitated access to the Japanese market.

However, if these alliances and linkages are not properly structured, they could have the long term, one-sided consequence of transferring knowledge and technology from the United States to Japan. For alliances and linkages to have long-term benefits to the U.S. and Japan, they must redress such structural weaknesses as manufacturing and process technology in the U.S. and generic research and new product design in Japan. The challenge for the U.S. semiconductor industry is to build knowledge and technology alliances and linkages that maximize the benefits of collaborating with Japan so that the U.S. remains a front-line player in all aspects of the semiconductor industry (National Research Council, 1992a).

U.S. and Japanese alliances and linkages in the semiconductor industry can be placed into the following categories: (a) R&D, (b) manufacturing, (c) marketing and service, and (d) general purpose. Until the early 1970s, the majority of alliances and linkages fell into the R&D category and consisted primarily of knowledge and technology being transferred from the U.S. to Japan. The 1980s witnessed an increase in the number of alliances and linkages in manufacturing. Overall, the number of U.S. and Japanese semiconductor-related alliances and linkages increased in the early 1990s, with the largest increase occurring in the marketing and service category. Alliances and linkages in the semiconductor industry are formed in order to (a) compensate for in-house weaknesses or technology gaps; (b) fill out product lines and portfolios; (c) position the company to enter new markets; (d) better serve an established or targeted customer base; and (e) reduce the costs, risks, and time required to develop new products and process technology. To reach these goals, U.S. and Japanese firms utilize assembly and testing, second-source, licensing, fabrication, and sales agency agreements; technology trades; product and process technology investments; and joint ventures and developments (National Research Council (1992a).

The National Research Council study concluded that the number of U.S. and Japanese alliances and linkages in the semiconductor industry will continue to increase for the foreseeable future. Indeed, as foreign markets expand, so, too, will the number of U.S. alliances and linkages with countries other than Japan increase. Consequently, alliances and linkages will continue to be the primary mechanisms by which knowledge and technology in the semiconductor industry are imported, absorbed, diffused, and applied for commercial purposes. How these alliances and linkages are structured, organized, and managed will influence, in large part, the percentage of the world's semiconductor market controlled by the U.S. However, as the study correctly points out, a variety of methods exists, outside the realm of alliances and linkages, through which knowledge and technology can be imported, absorbed, and diffused. Foreign countries and firms such as those in Japan have direct and open access to knowledge and technology in the public domain. Sources of *explicit knowledge* include research results published in books and journal articles and presented at technical and professional meetings, undergraduate and graduate training, consulting services, patent application disclosures, and participation in university-based research. *Tacit knowledge*, in the form of product and process technology, can be obtained by reverse engineering of existing products, consulting services, and hiring engineers and scientists. Finally, the study concludes that large Japanese firms view alliances and linkages from a longer term horizon and enter the relationship with the intention of learning as much as possible in order to strengthen their competitive position several years down the road. Their capacity for organizational learning and their management of knowledge and technology are matched by few firms in the United States (National Research Council, 1992a).

Japanese and U.S. Alliances and Linkages in LCA

The development of the Japanese aircraft industry is characterized by the interplay between the push for indigenously developed knowledge and technology by Japanese industry and the use of alliances and linkages to import, absorb, diffuse, and apply for commercial purposes external

knowledge and technology. In Japan the government has assisted the attainment of both objectives by providing direct and indirect financial support. The government of Japan also promotes the diffusion and integration of knowledge and technology by creating research consortia designed to develop the knowledge and technology needed by the domestic aircraft industry. The Japanese government promotes many alliances and linkages in the form of international partnerships (i.e., R&D consortia) for the purpose of acquiring (i.e., importing) knowledge and technology.

The National Research Council (1994) examined a wide range of U.S. and Japanese alliances and linkages relevant to the RD&P of LCA. The four Japanese "heavy" industries (Mitsubishi, Kawasaki, Fuji, and Ishikawajima-Harima) began working as suppliers for Boeing's 747 program, gradually increasing their participation to become subcontractors for Boeing's 737 and 757 programs. Their work share and technical sophistication increased with the 767 program and, over time, expanded to the status of "program partnership" in Boeing's 777 program. (Participation of the heavy industries was made possible by indirect government support and loans from the Japan Development Bank.) For its part, Boeing obtained market penetration by selling its airplanes to Japanese airlines; gained access to competitively priced, high-quality components; and spread a significant portion of the programs' financial risks. The Japanese "heavies" received knowledge and technology (e.g., data exchange and engineer training in advanced computer design techniques), long-term business, low-risk access to global aircraft markets, government support for their industry, and have developed a world-class manufacturing capability in aircraft structural component.

The Japanese "heavies" have made significant advances in manufacturing structural components (e.g., fuselage sections) for LCA. Combining the knowledge and technology acquired from U.S. military and commercial aircraft programs with their existing manufacturing capability in the automotive and other mass production industries, the Japanese "heavies" have developed a competitive advantage in terms of cost and quality. U.S. suppliers of LCA structural components will have to become particularly competitive in terms of price, quality, and delivery if they are to match or exceed their Japanese counterparts. However, to develop world-class manufacturing capabilities similar to those of the Japanese requires that U.S. subcontractors make large capital investments against the prospects of a significant business base. Nonetheless, the prospects of a constant or increasing business base for U.S. suppliers of LCA structural components is problematic, given that U.S. LCA manufacturers consider the purchase of foreign-made (i.e., Japanese) structural components a market penetration and sales wedge (National Research Council, 1994). Therefore, the likelihood of an increasing business base for U.S. suppliers must be viewed against the reality that foreign sales of U.S. manufactured LCA often include "offset" provisions that require work share and the transfer of knowledge and technology (Barber and Scott, 1995).

The Japanese aircraft industry places considerable importance on developing a world-class capability in the fabrication and manufacture of composite materials. Moreover, the Japanese government and the Japanese aircraft industry view materials fabrication and manufacture as an important entry point to participation in future international aircraft programs. The use and importance of composite materials in LCA will increase as the cost of their fabrication and manufacture decreases through learning-by-using and learning-by-doing. The Japanese "heavies" have coupled imported and domestic knowledge and technology with years of experience in incorporating composite materials into sporting goods and other consumer products. They have also invested substantially in manufacturing equipment and in product and process technology, and have thereby become very proficient in the fabrication and manufacture of composite material components for LCA. Furthermore, some of the leading producers of carbon fiber in the world are Japanese companies. In 1994, the Japanese firm Toray was the only qualified supplier of carbon

and resin fibers for the Boeing 777 composite tail. Through various aircraft programs that culminated in the FS-X, Mitsubishi Heavy Industries has developed the capability of manufacturing an entire composite wing in one piece in a process called "cocuring" (National Research Council, 1994).

The challenge for the U.S. is made difficult by several factors. The government-industry collaboration in developing composite materials leverages the strength of the Japanese industry's capabilities in manufacturing and product development, and it incorporates focused government-funded research programs that target emerging applications. Japanese companies have free access to the U.S. market. They are also free to form knowledge and technology alliances and linkages with U.S. companies. On the other hand, U.S. companies often have to form alliances and linkages with Japanese companies to acquire access to Japanese markets. Finally, Japanese firms have direct and open access to U.S.-created knowledge and technology that is in the public domain.

Lastly, we look at propulsion and avionics. Both U.S. aircraft engine producers, GE and Pratt & Whitney, have longstanding and extensive alliances and linkages with the Japanese "heavies." Likewise, both GE and Pratt & Whitney participate in the JSPTP or HYPR. The Japanese government has committed considerable funding for technology (i.e., high-performance materials) development and for upgrading Japan's engine development facilities. Government policy and corporate strategy combine to position Japan as a world leader in advanced propulsion materials and related critical technologies. Japanese government-industry collaboration has served to position the Japanese aircraft industry to continue to participate in international engine development programs at increased levels of technical and manufacturing responsibility. The dominant U.S. players in avionics, the Collins division of Rockwell International and Honeywell, have fairly extensive alliances and linkages with Japanese firms. In fact, both formed alliances with Japanese firms to produce the avionics for the Boeing 777. These linkages have become more important as the knowledge and technology for commercial avionics come less from defense R&D and more from consumer electronics (e.g., flat panel displays) and computer applications. From the U.S. perspective, the Japanese provide the best source for a cost-efficient solution and a reliable source of high value-added components at a reasonable price. To the Japanese, the benefits include long-term, profitable business and new applications for existing products; acquiring knowledge and technology; and learning about business methodology in a high-image market. Finally, the Japanese firms stand to increase their market for consumer electronics and computer applications as such features as passenger entertainment and communication systems become standard on new LCA (e.g., Boeing's 777) (National Research Council, 1994).

CONCLUSIONS

Kash (1992) states that successful innovation in the international marketplace requires three inputs—(a) capital, (b) labor, and (c) many kinds of ideas. The ideas referred to by Kash exist in the form of knowledge. In contrast to the United States, Japan places considerable importance on (both explicit and tacit) knowledge. Of Kash's three inputs, knowledge appears to be *the* important component of Japanese innovation. Although it is gradually changing, the traditional view in the U.S. is that "ideas for innovation" derive from basic or fundamental research, which is the recipient of considerable federal largesse, and from the "dual-use" provisions of (federally funded) military and space R&D. The dominant view in Japan is that ideas for new and improvements to existing products, processes, or services come from all points along the innovation spectrum, but particularly from design and development engineers who are linked to the marketing function of their firms and thereby to consumers. Furthermore, unlike the U.S.,

Japan appears to be bothered less by the "not invented here" (NIH) syndrome; ideas for product and process innovation can and often do come from outside the country, and typically they come from the United States (National Research Council, 1990).

Apart from the belief that it is fundamentally a *public* good in the United States and a *private* (corporate) good in Japan, knowledge in Japan is an intellectual, strategic, and competitive corporate asset. Japanese firms actively seek out, acquire (import), and use the best knowledge, both domestic and foreign, for innovation and product and process development. In contrast to the prevailing attitude in the U.S., the importance of knowledge is recognized by Japanese public policy, industries, and firms alike. Japanese public policy fosters research collaborations, alliances, and linkages (Ryutaro, Okuno, and Suzumura, 1988) as a means of accessing, importing, and diffusing (external) knowledge and technology (Granstrand, Bohlin, Oskarsson, Sjoberg, 1992), and government and industry work hand-in-hand to promote the acquisition and diffusion of knowledge (Rubinger, 1986). Overall, the Japanese appear better able than their foreign counterparts to use existing knowledge.

The diffusion of knowledge and technology is positively influenced by Japanese custom (Books, 1995), culture (Kingery, 1991; Saha, 1994; Tokusei, 1994; Johnson-Freese, 1993), the Japanese patent system (Kotler and Hamilton, 1995); industrial organization (Kenney and Florida, 1993), and management (Hull, Hage, and Azumi, 1985; Liker, Ettlie, and Campbell, 1995; Westney, 1986). Competitive intelligence in Japan has both a public and a private component and is a major contributor to technological innovation and product and process development (Fuld, 1988). In contrast, competitive intelligence practices in the U.S. have been limited to a few industries, most notably pharmaceuticals, and are frequently among the first activities to be eliminated in times of budgetary crises as they are not considered core business strategies. Furthermore, the ability to acquire and diffuse knowledge and technology is a critical factor in the career development and advancement of engineers and scientists in Japan, who experience regular and systematic transfers within their employing organizations and are consequently exposed to the entire spectrum of the R&D process (Lynn, Piehler, and Kieler, 1993; Wakasugi, 1992). Engineers and scientists in Japan and the United States appear to differ significantly in their information-use and -seeking behaviors, with the Japanese using more information and relying on more information sources and gatekeepers than their U.S. counterparts do (Lynn, Piehler, and Zahray, 1988).

Japan employs a variety of public policies and strategies to facilitate the development of industries (and firms) that are at the forefront of technological development. A salient feature of these policies and strategies has been the "targeting" of certain high technology industries and firms as recipients of special state attention and largesse. The targeted industries and firms are almost always "knowledge-intensive" organizations that generate a substantial multiplier or spill-over of adaptable knowledge for use by other industries. Aircraft production, LCA in particular, is one such industry. Japan has targeted the aircraft industry as one of three key technologies for the twenty-first century. Coveted for its knowledge and technological linkages to a variety of other high-value added industries, aeronautical R&D is viewed as a knowledge-intensive endeavor, the results of which are applicable to and can be "spun on" to a wide range of disciplines and industries. Progress in aeronautics, which can promote advancements in a number of technologies, is critical for the development of technologically-oriented societies such as Japan (March, 1989). To the government of Japan, aircraft production provides knowledge and technology that complement the country's strengths in design, development, and manufacturing. Under the rubric of national security, foreign policy, and international trade and cooperation, the U.S. government has actively promoted the flow of aeronautical knowledge and technology to Japan.

Alliances and linkages continue to be a mainstay of Japanese industrial policy. The record indicates that alliances between the government of Japan and Japanese industry have produced mixed results. In fact, a recent *Newsweek* article (Bartholet, 1997), citing Japan's failure in high definition television (HDTV) and the fifth-generation computer, states that the old Japanese way of doing business—whereby government mandates and industry implements—does not work well any more. On the other hand, the article states that Japanese industry has and will continue to successfully use alliances and linkages to "become competitive" in industries and technologies such as semiconductors and to become "players" in industries and technologies such as biotechnology. According to Heaton (1988), Japan seized upon alliances and linkages as a public policy initiative in the 1960s as a strategy for importing, adapting, and diffusing Western knowledge and technology throughout Japanese industry. Heaton further states that this strategy promised to improve the competitiveness of Japanese industry in international markets within a short period of time. Researcher and scholars generally agree that Japan has succcessfully used alliances and linkages to develop a substantial capability in the RD&P of LCA. They differ somewhat in their opinions regarding two points.

First, Japan has developed an indigenous capability in helicopters and civil aircraft. Technically, Japan has the ability to build an LCA. However, it is unlikely that Japan will develop an indigenous LCA. Defenders of this position, argue that the industry dynamics in LCA are very different from those in biotechnology and semiconductors. Specifically, they state that the R&D requirements are considerably higher, the up-front capital outlays are enormous, and the learning curves are more steep than those that exist in other industries. Finally, there is the fact that the world market is already dominated by two major LCA players–thus making the potential for a third to overcome the barriers to entry and achieve any economies of scale in the process–somewhat daunting. The correct scenario, they predict, is that Japanese industry will become "a" or "the" dominant global subcontractor in LCA production. If true, the concern of U.S. policymakers then becomes one of "what impact is the creation of a dominant global subcontractor in Japan likely to have on the continued viability of existing U.S. LCA subcontractors"? *Second*, is the issue of "set asides" of knowledge, technology, and jobs for market access. Researchers such as Barber and Scott (1995) predict direr consequences in terms of lost jobs and the one-way flow of knowledge and technology. The arguments against trading jobs for market access become more intense when the knowledge and technology being exported are paid for, in part, by federal funds expended by the DoD and NASA and are being used in an industry that is the leading contributor to the nation's balance of trade. Warnings concerning the exportation of knowledge and technology are not new. Indeed, the evidence is overwhelming that during the 1970s and early 1980s, Japan received about $15 billion worth of American knowledge and technology for which they paid a mere $1.5 billion in the form of royalties, licensing fees, and out right purchases (Winpisinger, 1978). Although those taking a "free trade" position argue that the unrestrained flow of knowledge and technology is essential for American firms to remain competitive in today's global economy, supporters of "managed" trade state that knowledge and technology are not esthetic pursuits like music or poetry but rather they are commodities having economic and commercial value with investment costs that can be measured, a dollar value that can be computed, and a clear market advantage for those who will manage them as intellectual and strategic assets. Perhaps the question for U.S. policymakers then is "can government and industry work more closely together to guarantee that, on the one hand, the U.S. LCA sector remains preeminent in the world while, on the other hand, ensuring that knowledge, technology, and jobs are not lost in the process"?

IMPLICATIONS FOR U.S. PUBLIC POLICY, DIFFUSING KNOWLEDGE AND TECHNOLOGY, AND LCA

In Chapter 2, we stated that the creation and utilization of knowledge and technology constitute distinct but equally complex and multifaceted aspects of the knowledge diffusion process. The former concentrates on producing new knowledge whereas the latter focuses on the transfer and use of that knowledge. Chapters 3 and 4 clearly demonstrate that U.S. public policy places much greater emphasis on knowledge creation (i.e., funding basic research) than on knowledge diffusion (i.e., funding the transfer and use of knowledge). Based on our analysis of the research and literature, the following U.S. public policy initiatives are recommended.

Adopting a Diffusion-Oriented Technology Policy

Our analysis reveals that Japanese public policies incorporate many of the "diffusion-like" features identified previously in Chapters 3, 4, and 17. Chief among these are the capacity for adjusting to technological change across the entire industry structure and the effective diffusion and management of imported and domestically produced knowledge and technology. In contrast, the dominant U.S. political view holds that the transfer and use of publicly funded knowledge and technology, together with the design, development, and production of products, processes, and services, should be left to the private sector. If U.S. industry is to enjoy a competitive advantage based on the use of publicly funded knowledge and technology, U.S. policymakers need to recognize the importance of and move towards a more diffusion-oriented policy framework. As Branscomb (1993) notes, accelerating the speed with which knowledge and technology are diffused is a key element in a national competitiveness strategy. But acceleration is not the *only* factor. Ensuring that publicly funded knowledge and technology first reaches the individuals and organizations that helped fund it is even more critical if the knowledge is to provide them with a competitive edge in the global marketplace.

Utilizing Knowledge Management As a Component of a Diffusion-Oriented Technology Policy

In an attempt to maintain and regain its strength in world markets, U.S. industry is improving the quality of its products and getting them to market faster. What is emerging is an enterprise model that borrows from Japan's *keiretsu*, (which is not unlike the "groupement" arrangement adopted by the Europeans for the RD&P of the Airbus aircraft) which rely on cooperation among a group of manufacturers, suppliers, and financial companies. Such U.S. legislation as the National Cooperative Research Act has enabled U.S. industries to pool their resources to do "precompetitive" research on technology used for distinctive products. More than 250 R&D consortiums have been created to date and many U.S. firms participate in several consortia. In order to help create a more competitive environment and support for U.S. industry, a diffusion-oriented policy framework should seek to accommodate the following three knowledge diffusion-knowledge management objectives.

Optimize the diffusion and absorption of knowledge and technology resulting from federally funded R&D to enhance economic competitiveness. This requires that the knowledge base (i.e., the results of federally funded R&D) be managed as a capital asset and that a strategy, an infrastructure, and mechanisms be developed that ensure the diffusion and absorption of domestically- and foreign-produced knowledge and technology. The mechanisms should be user-focused and the available knowledge and technology should be modelled in a user-oriented problem-based context. Information technology and (human) intermediaries, similar to those used in the agriculture and manufacturing extension programs, would facilitate delivery of both codified

(explicit) and uncodified human (tacit) knowledge that could then be readily analyzed and absorbed by users for problem-solving purposes.

Optimize the diffusion and absorption of knowledge and technology produced outside of the United States. This initiative requires an understanding of the scope and value of work being performed in other countries, the facilities at which the work is being conducted, and who the experts are that are conducting the work. A mechanism is needed for collecting, analyzing, and integrating foreign-produced knowledge and technology into the U.S. knowledge base.

Optimize the diffusion and absorption of knowledge through cooperative ventures. This initiative requires increased use of aeronautical technology demonstration programs involving DoD, FAA, NASA, industry, and universities. Such programs are recognized as relatively successful in diffusing the results of federally funded R&D. Greater use of personnel exchange programs among government, industry, and academic sectors would also enhance diffusion and absorption.

LCA Knowledge and Technology Alliances and Linkages

Finally, as noted in Chapters 1 and 2, there are frequently intended and unintended consequences of U.S. public policy. The intended purpose of U.S. public policy during the Cold War was to restore a measure of Japan's defensive capability. An unintended consequence was that Japan became the United States' economic competitor overall (Reich and Mankin, 1986) and challenged the superiority of the U.S. aircraft component suppliers through strategic alliances and linkages with U.S. LCA manufacturers. Challenging an industry that is critical to economic growth and national security represents a serious threat to the United States. U.S.–Japanese knowledge and technology alliances and linkages are a necessary reality that must be managed to guarantee a balanced, two-way flow of knowledge and technology and to ensure U.S. pre-eminence in aeronautics. With respect to U.S.–Japanese knowledge and technology alliances and linkages, U.S. public policy should support the following four objectives.

Maintain U.S. technological leadership. Maintaining technological leadership requires the creation of a policy framework that embraces all aspects (e.g., intellectual property) of the process of technological innovation; greater coordination and cooperation between the Congress and the Executive branch and among academia, industry, and government; and a long-term view. Maintaining leadership also requires increased cooperation among U.S. firms and greater use of knowledge and technology alliances and linkages. Leadership requires industry and government to keep high paying, value-added jobs in the U.S. and to protect the product and process integration skills that underlie the competitive status of the U.S. aircraft industry.

Revitalize U.S. manufacturing capabilities. U.S. industry and government should work together improve existing manufacturing performance in terms of cost, quality, and delivery. Public policy should focus on increasing and sharing the pool of knowledge, technology, and experience relative to aircraft development and production and provide incentives for industry to invest in equipment and employee training (Cohen and Zyman, 1987; Winpisinger, 1978).

Encourage mutually beneficial U.S.-Japan alliances and linkages. Greater thought and examination on the part of industry and government must be applied to determining the justification (i.e., goals, objectives, and measured outcomes) underlying U.S.-Japan alliances and linkages. Those that offer U.S. industry short-term benefits but have long-term adverse consequences should be avoided. U.S. government and industry should create mechanisms and devote additional resources to encouraging mutually beneficial U.S.-Japan alliances and linkages

in the following areas: (a) technical information, (b) technology benchmarking, (c) identifying and managing critical knowledge and technologies, and (d) education and training (National Research Council, 1994).

Ensure a level playing field for global competition. Eternal vigilance is required on the part of industry and government to ensure continued U.S. leadership in LCA. Therefore, alliances and linkages that transfer high paying, value-added jobs and complex manufacturing production from the U.S. to Japan and other countries should be avoided. Existing Japanese government-industry relationships that include low interest loans and other incentives artificially increases the competitive position of Japanese industry and places U.S. subcontractors at a disadvantage should be challenged through the World Trade Organization. Enforcement of intellectual property rights should be vigorously pursued. Consequently, U.S. public policy, as recommended by the National Research Council (1994), should seek to ensure that the policies of Japan and other countries do not place U.S. industry at a competitive disadvantage.

REFERENCES

Arrison, T.S.; C.F. Bergsten; E.M. Graham; and M.C. Harris. (eds.) (1992). *Japan's Growing Technological Capability: Implications for the U.S. Economy*. Washington, DC: National Academy Press.

Badaracco, J.L. (1991). *The Knowledge Link: How Firms Compete through Strategic Alliances*. Boston, MA: Harvard University Press.

Barber, R. and R.E. Scott. (1995). *Jobs on the Wing: Trading Away the Future of the U.S. Aerospace Industry*. Washington, DC: Economic Policy Institute.

Bartholet, J. (1997). "Diming the Sun: The Alliances of Japanese Bureaucrats and Businessmen Doesn't Work Well Anymore." *Newsweek* (March 17th) CXXIX(11): 38-39.

Basadur, M. (1992). "Managing Creativity: A Japanese Model." *Academy of Management Executive* 6(2): 29-42.

Branscomb, L.M. (ed.). (1993). *Empowering Technology: Implementing a U.S. Strategy*. Cambridge, MA: MIT Press.

Books, M.J.A. (1995). *Communication Styles of Japanese and Americans: Six Key Styles Explored*. Unpublished Doctoral Dissertation. Cincinnati, OH: The Union Institute. (Available UMI 9542658.)

Buckett, M.I. (1991). "The Japanese Research Environment: A Student's View From Within." In *Japanese/American Technological Innovation: The Influence of Cultural Differences on Japanese and American Innovation in Advanced Materials*. W.D. Kingery, ed. New York, NY: Elsevier, 81-89.

Cheney, D.W. and W.W. Grimes. (1991). *Japanese Technology Policy: What's the Secret*. Washington, DC: Council on Competitiveness.

Chinworth, M.W. (1992). *Inside Japan's Defense: Technology, Economics, and Strategy*. Washington, DC: Brassey's.

Cohen, S.S. and J. Zyman. (1987). *Manufacturing Matters: The Myth of the Post-Industrial Economy*. New York, NY: basic Books.

Cohen, W. and D. Levinthal. (1990). "Absorptive Capability: A New Perspective on Learning and Change." *Administrative Science Quarterly* (35): 128-152.

Crane, D. (ed.). (1995). *The Sociology of Culture*. Cambridge, MA: BlackwellCravens, D.W.; H.K. Downey; and P. Lauritano. (1992). "Global Competition in the Commercial Aircraft Industry: Positioning for Advantage by the Triad Nations." *Columbia Journal of World Business* (Winter) 26(4): 46-58.

Council on Competitiveness. (1996). *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness*. Washington, DC: Council on Competitiveness.

Culter, R.S. (1989). "A Comparison of Japanese and U.S. High-Technology Transfer Practices." *IEEE Transactions on Engineering Management* (February) 36(1): 17-24.

Ergas, H. (1987). "Does Technology Policy Matter?" In *Technology and Global Industry: Companies and Nations in the World Economy*. B.R. Guile and H. Brooks, eds. Washington, DC: National Academy Press, 191-245.

Ford, J.B. and E.D. Honeycutt, Jr. (1992). "Japanese National Culture as a Basis For Understanding Japanese Business Practices." *Business Horizons* (November) 35(6): 27-34.

Frankel, J.A. and M. Kahler (eds.). (1993). *Regionalism and Rivalry: Japan and the United States in Pacific Asia*. Chicago, IL: University of Chicago Press.

Fransman, M. (1991). "What We Know About the Japanese Innovation System and What We Need to Know." In the *Proceedings of the NISTEP International Conference on Science and Technology Policy Research*. Inose, H.; M. Kawasaki; and F. Kodama, eds. Tokyo, Japan: Mita Press, 445-463.

Frenkel, O. (1984). "Flying High: A Case Study of Japanese Industrial Policy." *Journal of Policy Analysis and Management* (Spring) 3(3): 406-420.

Friedman, D.A. and R.J. Samuels. (1993). "How to Succeed Without Really Flying: The Japanese Aircraft Industry and Japan's Technology Ideology." Chapter 7 in *Regionalism and Rivalry: Japan and the United States in Pacific Asia*. J.A. Friedman and R.J. Samuels, eds. Chicago, IL: University of Chicago Press, 251-320.

Fuld, L.M. (1988). *Monitoring the Competition*. New York, NY: John Wiley.

Goldman, A. (1994). *Doing Business With the Japanese*. Albany, NY: State University of New York Press.

Golick, V.L. (1992). "From Competition to Collaboration: The Challenge of Commercial-Class Aircraft Manufacturing." *International Organization* (Autumn) 46(4): 900-934.

Granstrand, O.; E. Bohlin; C. Oskarsson; and N. Sjoberg. (1992). "External Technology Acquisition in Large Multi-Technology Corporations." *R&D Management* 22(2): 111-133.

Gudykunst, W.B. (ed.). (1993). *Communication in Japan and the United States*. Albany, NY: State University of New York Press.

Gudykunst, W.B. and T. Nishida. (1993). "Interpersonal and Intergroup Communication in Japan and the United States." Chapter 6 in *Communication in Japan and the United States*. Albany, NY: State University of New York Press, 149-214.

Hall, E.T. and M.R. Hall. (1987). *Hidden Differences: Doing Business With the Japanese*. Garden City, NJ: Anchor Press/Doubleday.

Hall, G.R. and R.E. Johnson. (1970). "Transfers of United States Aerospace Technology to Japan." Chapter 7 in *The Technology Factor in International Trade*. R. Vernon, ed. New York, NY: Columbia University Press, 305-358.

Hansen, J.H. (1996). *Japanese Intelligence: The Competitive Edge*. Washington, DC: National Intelligence Book Center.

He, X-H. (1993). "Japanese Strategy For Improving National Technological Competitive Bases." In the *Proceedings of the Third NISTEP International Conference on Science and Technology Policy Research*. Okamura, S; F. Sakauchi; and I. Nonaka, eds. Tokyo, Japan: Mita Press, 149-161.

Heaton, G.R. (1989). "Commercial Technology Development: A New Paradigm of Public-Private Cooperation." *Business in the Contemporary World* (Autumn): 87-98.

Heaton, G.R. (1988). "The Truth About Japan's Cooperative R&D." *Issues in Science and Technology* (Fall) 5(1): 32-40.

Hedlund, G. and I. Nonaka. (1993). "Models of Knowledge Management in the West and Japan." Chapter 5 in *Implementing Strategic Processes: Change, Learning and Cooperation*. P. Lorange; B. Chakravarthy; J. Roos; and A. Van de Ven, eds. Oxford, UK: Blackwell Publishers, 117-144.

Herbig, P. (1995). *Innovation Japanese Style: A Cultural and Historical Perspective*. Westport, CT: Quorum Books.

Hull, F.M.; J. Hage; and K. Azumi. (1985). "R&D Management Strategies: America Versus Japan." *IEEE Transactions on Engineering Management* (May) EM-32(2): 78-83.

Imai, K. (1991). "Japan's National System of Innovation." In the *Proceedings of the NISTEP International Conference on Science and Technology Policy Research*. Inose, H.; M. Kawasaki; and F. Kodama, eds. Tokyo, Japan: Mita Press, 97-134.

Inaba, H. (1988). *Theoretical Framework of Cross-Cultural Comparison: Re-examination of Studies on Japanese Communication Patterns*. Unpublished Master's Thesis. East Lansing, MI: Michigan State University. (Available UMI 1334450.)

Johnson, C. (1982). *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975*. Stanford, CA: Stanford University Press.

Johnson-Freese, J. (1993). *Over the Pacific: Japanese Space Policy Into the Twenty-First Century*. Dubuque, IA: Kendall-Hunt.

Kash, D.E. (1992). "Innovation Policy." In the *Proceedings of the Second NISTEP International Conference on Science and Technology Policy Research*. Okamura, S; K. Murakami; and I. Nonaka, eds. Tokyo, Japan: Mita Press, 139-148.

Kato, H. and J.S. Kato. (1992). *Understanding and Working With the Japanese Business World*. Englewood Cliffs, NJ: Prentice Hall.

Kenney, M. and R. Florida. (1993). *Beyond Mass Production: The Japanese System and its Transfer to the U.S.* New York, NY: Oxford University Press.

Killing, J.P. (1980). "Technology Acquisition: License Agreement or Joint Venture." *Columbia Journal of World Business* (Fall) 15(3): 38-46.

Kingery, W.D. (ed.). (1991). *Japanese/American Technological Innovation: The Influence of Cultural Differences on Japanese and American Innovation in Advanced Materials*. New York, NY: Elsevier.

Kokubo, A. (1993). "Competitive Intelligence." *IEEE Spectrum* (August) 30(8): 44-46.

Kokubo, A. (1992). "Japanese Competitive Intelligence for R&D." *Research Technology Management* (January) 35(1): 33-34.

Komiya, R.;M.Okuno; and K. Suzumura. (eds.). (1988). *Industrial Policy of Japan*. San Diego, CA: Academic Press.

Kotler, M.L. and G.W. Hamilton. (1995). *A Guide to Japan's Patent System*. Washington, DC: Office of Technology Policy, U.S. Department of Commerce. (Available NTIS: PB96-129135.)

Lebra, T.S. (1993). "Culture, Self, and Communication in Japan and the United States." In *Communication in Japan and the United States*. Albany, NY: State University of New York Press, 51-87.

Leonard-Barton, D. (1995). *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovations*. Boston, MA: Harvard Business School Press.

Levitt, T. (1988). "The Globalization of Markets." *Harvard Business Review* (May/June) 61(3): 92-102.

Lewis, J.D. (1995). *The Connected Corporation: How Leading Companies Win Through Customer-Supplier Alliances*. New York, NY: The Free Press.

Liker, J.K.; J.E. Ettlie; and J.C. Campbell. (1995). *Engineered in Japan: Japanese Technology-Management Practices*. New York, NY: Oxford University Press.

Lopez, V.C. and H.R. Hertzfeld. (1991). "Japan and the Asia-Pacific Rim Aerospace Industry: Its Market, Structure, and International Relationships." In *The U.S. Aerospace Industry in the 1990s: A Global Perspective*. Washington, DC: Aerospace Industries Association of America, Inc., 59-76.

Lynn, L.H.; H.R. Piehler; and M. Kieler. (1993). "Engineering Careers, Job Rotation, and Gatekeepers in Japan and the United States." *Journal of Engineering and Technology Management* 10: 53-77.

Lynn, L.H.; H.R. Piehler; and W.P. Zahray. (1988). *Engineering Graduates in the United States and Japan: A Comparison of Their Careers and Methods of Information Transfer*. Pittsburgh, PA: Carnegie Mellon University. (Available as NSF Final Grant Report SRS-84099836.)

Maher, T.E. and Y.Y. Wong. (1994). "The Impact of Cultural Differences on the Growing Tensions Between Japan and the United States." *SAM Advanced Management Journal* (December) 59(1): 40-46.

Makino, N. (1987). *Decline and Prosperity: Corporate Innovation in Japan*. Tokyo, Japan: Kodansha International.

Mansfield, E. (1989). "Technological Creativity: Japan and the United States." *Business Horizons* (March/April) 32(2): 1157-1167.

Mansfield, E. (1988). "The Speed and Cost of Industrial Innovation in Japan and the United States: External VS. Internal Technology." *Management Science* (October) 34(10): 1157-1167.

March, A. (1989). *The US Commercial Aircraft Industry and its Foreign Competitors*. MIT Commission on Industial Productivity Working Paper. Cambridge, MA: Commission Working Group on the Aircraft Industry.

Matsuda, S. (1991). "Japanese Culture and Innovation." In *Japanese/American Technological Innovation: The Influence of Cultural Differences on Japanese and American Innovation in Advanced Materials*. W.D. Kingery, ed. New York, NY: Elsevier, 105-115.

McNamara, T. and K. Hayashi. (1994). "Culture and Management: Japan and the West Towards a Transnational Corporate Culture." *Management Japan* 27(2): 3-13.

Melloan, G. (1988). "An American Views Japan's Patent Copycat Culture." *Wall Street Journal* (Tuesday, July 12 th.): 29.

Merifield, B. (1989). "Strategic Alliances in the Global Marketplace." *Research–Technology Management* (February) 32(1): 15-20.

Moran, T.H. and D.C. Mowery. (1994). "Aerospace and National Security in an Era of Globalization." Chapter 8 in *Science and Technology Policy in Interdependent Economies*. Boston, MA: Klumer Academic Publishers, 173-198.

Morita, I.T. (1991). "Japanese Technical Information." In the *Encyclopedia of Library and Information Science*. *48*. (Supplement 11). New York, NY: Marcel Dekker.

Mowery, D.C. (1994). "Balancing Benefits and Obligations Within the Global R&D System: The Changing Position of Japan." Chapter 6 in *Science and Technology Policy in Interdependent Economies*. Boston, MA: Klumer Academic Publishers, 125-151.

Mowery, D.C. (1990). "The Japanese Commercial Aircraft Industry: *Déjà Vu* All Over Again?" *Technovation* (September) 10(6): 419-439.

Mowery, D.C. (1987). "Country Strategies." Chapter 4 in *Alliance Politics and Economics: Multinational Joint Ventures in Commercial Aircraft*. Cambridge, MA: Ballinger Publishing, 107-145.

Mowery, D.C. and N. Rosenberg. (1985a). *The Japanese Commercial Aircraft Industry Since 1945: Government Policy, Technical Development, and Industrial Structure*. An Occasional Paper of the Northeast Asia-United States Forum on International Policy. Stanford, CA: Stanford University Press.

Mowery, D.C. and N. Rosenberg. (1985b). "Commercial Aircraft: Cooperation and Competition Between the U.S. and Japan." *California Management Review* (Summer) 27(4): 70-92.

Mowery, D.C. and D.J. Teece. (1993). "Japan's Growing Capabilities in Industrial Technology: Implications for U.S. Managers and Policymakers." *California Management Review* (Winter) 35: 9-34.

Moxon, R.W.; W. Gerginger; and J. Michael. (1985). "Multinational Ventures in the Commercial Aircraft Industry." *Columbia Journal of World Business* (Summer) 20(2): 55-62.

Nakane, C. (1972). "Human Relations in Japan: Summary Translation of 'Tateshakai No Ningen Kankei' (Personal Relations in a Vertical Society)." Tokyo, Japan: Ministry of Foreign Affairs.

National Research Council. (1994). *High-Stakes Aviation: U.S.–Japan Technology Linkages in Transport Aircraft*. Washington, DC: National Academy Press.

National Research Council. (1992a). *U.S.-Japan Strategic Alliances in the Semiconductor Industry: Technology Transfer, Competition, and Public Policy*. Washington, DC: National Academy Press.

National Research Council. (1992b). *U.S.-Japan Technology Linkages in Bio-Technology: Challenges for the 1990s*. Washington, DC: National Academy Press.

National Research Council. (1990). *Learning the R and D System: Industrial R&D in Japan and the United States*. Washington, DC: National Academy Press. (Available NTIS: PB91-130427.)

Niwa, F. and H. Goto. (1993). "Japanese Collaborative R&D: An Analysis of the Present Structures in Order to Determine Future Trends." Chapter 10 in *R&D Strategies in Japan: The National, Regional, and Corporate Approach*. H. Eto, ed. Amsterdam, The Netherlands: Elsevier, 207-224.

Nonaka, I; and H. Takeuchi. (1995). *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York, NY: Oxford University Press.

Odagiri, H. and A. Goto. (1993). "The Japanese System of Innovation: Past, Present, and Future." Chapter 3 in *National Innovation Systems: A Comparative Analysis*. R.R. Nelson, ed. New York, NY: Oxford University Press, 76-114.

Ohmae, K. (1989). "The Global Logic of Strategic Alliances." *Harvard Business Review* (March-April) 89(2): 143-154.

Ohsumi, H. (1995). "Cultural Differences and Japan-U.S. Economic Frictions." *Tokyo Business Today* (February) 63(2): 49-52.

Okimoto, D.I. (1986). "The Japanese Challenge in High Technology." In *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. R. Landau and N. Rosenberg, eds. Washington, DC: National Academy Press, 541-114.

Ouchi, W. and M. Bolton. (1988). "The Logic of Joint Research and Development." *California Management Review* (Spring): 9-33.

Peck, M.J. and A. Goto. (1981). "Technology and Economic Growth: The Case of Japan." *Research Policy* 10(3): 222-243.

Phillips. J.R. (1993). "Working Culture and Everyday Science in Japan: Creativity and the Status Quo." Chapter 12 in *R&D Strategies in Japan: The National, Regional, and Corporate Approach*. H. Eto, ed. Amsterdam, The Netherlands: Elsevier, 297-314.

Pister, K.S. (1988). "Mobilizing R&D for Economic War: Advice to the Next President." *Issues in Science and Technology* (Winter) 4(2): 70-73.

Reich, R.B. and E.D. Mankin. (1986). "Joint Ventures With Japan Give Away Our Future." *Harvard Business Review* (March-April) 86(2): 78-86.

Roehl, T. and J.F. Truitt. (1987). "Japanese Industrial Policy in Aircraft Manufacturing." *International Marketing Review* (Summer): 21-32.

Rubinger. B. (1986). "Technology Policy in Japanese Firms: Decision-Making, Supplier Links, and Technical Goals." In *Technology in the Modern Corporation: A Strategic Perspective*. M. Horwitch, ed. New York, NY: Pergamon, 184-199.

Ryutaro, K; M. Okuno; and K. Suzumura. (eds.). (1988). *Industrial Policy of Japan*. New York, NY: Academic Press.

Sabbagh, K. (1996). "The Bowing Company." Chapter 11 in the *21st-Century Jet*. New York, NY: Schribner, 178-188.

Saha, A. "Culture and the Development of Technology in Japan." *Technology in Society* 16(2): 225-241.

Sakakibara, K. and D.E. Westney. (1992). "Japan's Management of Global Innovation: Technology Management Crossing Borders." Chapter 12 in *Technology and the Wealth of Nations*. N. Rosenberg; R. Landau; and D.C. Mowery, eds. Stanford, CA: Stanford University Press, 327-343.

Samuels, R.J. (1994). *Rich Nation, Strong Army: National Security and the Technological Transformation of Japan*. Ithaca, NY: Cornell University Press.

Samuels, R.J. and B.C. Whipple. (1989a). "Defense Production and Industrial Development: The Case of Japanese Aircraft." Chapter 7 in *Politics and Productivity: The Real Story of Why Japan Works*. C. Johnson; L.D. Tyson; and J. Zysman, eds. Cambridge, MA: Ballinger Publishing, 275-318.

Samuels, R.J. and B.C. Whipple. (1989b). "The FSX and Japan's Strategy for Aerospace." *Technology Review* (October) 92(7): 42-51.

Schwartz, K. (1996). "Making Jets a Global Effort: Practical, Political Costs Demand Cooperation." *Daily Press* (Tuesday, December 3rd.): B6-B7.

Shear, J. (1994). *The Keys to the Kingdom: The FS-X Deal and the Selling of America's Future to Japan*. New York, NY: Doubleday.

Smitka, M.J. (1991). *Competitive Ties: Subcontracting in the Japanese Automotive Industry*. New York, NY: Columbia University Press.

Stewart, E.C. (1987). "The Japanese Culture of Organizational Communication." Chapter 7 in *Organization–Communication: Emerging Perspective II*. L. Thayer, ed. Norwood, NJ: Ablex.

Todd, D. and J. Simpson. (1986). "Aerospace and Development." Chapter 8 in *The World Aircraft Industry*. Dover, MA: Auburn House Publishing.

Tokusei, A. (1994). *The Cultural Coping Processes of Japanese and Americans at Japanese Automotive Transplants in North America*. Unpublished Doctoral Dissertation. Los Angeles, CA: University of California at Los Angeles. (Available UMI 9517721.)

Tudjman, M. (1991). "Culture and Information Society: The Japanese Way." *Information Processing & Management* 27(2/3): 229-243.

U.S. Congress, General Accounting Office. (1992). *Technology Transfer: Japanese Firms Involved in F-15 Co-production and Civil Aircraft Programs*. GAO/NSIAD-92. (Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives.) Washington, DC: General Accounting Office.

U.S. Congress, Office of Technology Assessment. (1991). "Government Support of the Large Commercial Aircraft Industries of Japan, Europe, and the United States." Chapter 8 in *Competing Economies: America, Europe, and the Pacific Rim*. OTA-ITE-498. Washington, DC: Office of Technology Assessment.

Wakasugi, R. (1992). "Why Are Japanese Firms So Innovative in Engineering Technology?" *Research Policy* 21: 1-12.

Westney. D.E. (1993). "Country Patterns in R&D Organization: The United States and Japan." Chapter 2 in *Country Competitiveness: Technology and the Organizing of Work*. B. Kogut, ed. New York, NY: Oxford University Press, 36-53.

Westney. D.E. (1986). "The Role of Japan-Based R&D in Global Technology Strategy." In *Technology in the Modern Corporation: A Strategic Perspective*. M. Horwitch, ed. New York, NY: Pergamon, 217-231.

Winpisinger, W.W. (1978). "The Case Against Exporting U.S. Technology." *Research Management* (March) 21(2): 19-21.

Wyatt, G. (1986). *The Economics of Invention: A Study of the Determinants of Inventive Activity*. New York, NY: St. Martin's Press.

Yoshino, M.Y. (1986). "Global Competition in a Salient Industry: The Case of Civil Aircraft." Chapter 16 in *Competition in Global Industries*. M.E. Porter, ed. Boston, MA: Harvard Business School Press, 517-538.

Yoshino, M.Y. and U.S. Rangan. (1995). *Strategic Alliances: An Entrepreneurial Approach to Globalization*. Boston, MA: Harvard University Press.